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Results of the Drilling Fluids Research Program Sponsored by the Gulf Breeze Environmental Research Laboratory, 1976-1984 and Their Application to Hazard Assessment

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RESULTS OF THE DRILLING FLUIDS RESEARCH PROGRAM SPONSORED BY THE GULF BREEZE ENVIRONMENTAL RESEARCH LABORATORY, 1976-1984, AND THEIR APPLICATION TO HAZARD ASSESSMENT

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16. ABSTRACT
The Environmental Research Laboratory, Gulf Breeze, FL, carried out a research program to evaluate the potential impact of drilling fluids on the marine environment from 1976-1983.

Results showed that drilling fluids can be toxic to marine animals at certain concentrations and exposure regimes. Drilling fluids can adversely affect animals through physical contact or physiologically. While some components that are toxic, such as pentachlorophenol, are no longer permitted for fluids released on the OCS, diesel oil is a toxic component of used fluids collected recently from the Gulf of Mexico.

Models developed to predict the impact of drilling fluids on open, well-mixed marine environments suggested that under "normal" operating conditions, most detectable adverse effects will be limited to within several hundred meters of the point of discharge. Exceptions could occur when drilling conditions are "abnormal" or when drilling rigs are near sensitive biological areas, such as coral reefs, or in poorly flushed areas.

Incomplete research data were acquired in some areas, and further research would be desirable in the following other areas: validation of models developed to predict the fate and effects of drilling fluids; the impact of additives on the toxicity of whole drilling fluids; sublethal effects of drilling fluids on sensitive life stages of organisms, particularly benthos; and the impact of drilling fluids that contain diesel oil, or chemicals used in place of diesel oil, on structure and function of benthic communities.

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FOREWORD

The protection of our estuarine and coastal areas from damage caused by toxic organic pollutants requires that regulations restricting the introduction of these compounds into the marine environment be formulated on a sound scientific basis. Accurate information describing concentration-response relationships for organisms and ecosystems under varying conditions is required. The Environmental Research Laboratory, Gulf Breeze, contributes to satisfying this information requirement through research programs aimed at determining:

- the effects of toxic organic pollutants on individual species and communities of organisms.
- the effects of toxic organics on ecosystems processes and components.
- the significance of chemical carcinogens in estuarine and marine environments.

This report summarizes the findings of academic, industry, and government scientists involved in a cooperative research effort to evaluate the impact of drilling fluids on the marine environment. Effort was made to relate the data on environmental concentrations and effects to a hazard or risk assessment. Results of this research will provide the regulatory arm of the Agency, and others, an additional data base on the fate and effects of drilling fluids that can be applied to the permitting process.

Henry F. Enos

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ABSTRACT

The Environmental Research Laboratory, Gulf Breeze, Florida, carried out a research program from 1976-1984 to evaluate the potential impact of drilling fluids on the marine environment. Research efforts were accomplished mainly through cooperative agreements with academic institutions and contracts with private laboratories; program direction and toxicity testing with used and generic drilling fluids were provided by the Gulf Breeze staff.

Results of research activities reported from this research program showed that drilling fluids are toxic to marine animals at certain concentrations and exposure regimes. Further, drilling fluids can adversely affect animals, especially benthos, through physical contact by burying or altering substrate composition. The fluids, or components of the fluids, also can exert effects by disrupting essential physiological functions of organisms. While some components (pentachlorophenol, for example) that are toxic are no longer permitted for fluids released on the OCS, research indicated that a "diesel" contaminant is a toxic component of used fluids recently collected from the Gulf of Mexico. Tests also showed that the addition of #2 fuel oil (diesel) or mineral oil increased the toxicity of laboratory-prepared drilling fluids.

Models developed to predict the impact of drilling fluids on open, well-mixed, and relatively deep (>20 meters) marine environments suggested that under normal operating conditions most detectable adverse effects should be limited to within several hundred meters of the point of discharge. Possible exceptions to this generalization could occur when drilling conditions differ from normal or when drilling rigs are located near sensitive biological areas, such as coral reefs, or in poorly flushed areas.

Incomplete research data were acquired in some areas, and further research would be desirable in other areas. For example, models developed to predict the fate and effects of drilling fluids should be field tested to validate the assumptions and inputs into the models. Special emphasis should be placed on discharges from multiple development rigs. Also, data and methodology are needed on the effects of additives, particularly biocides and chemicals to improve lubricity, on the toxicity of drilling fluids. Additional information on sublethal and chronic effects of the drilling fluids on sensitive life stages of organisms, particularly benthic organisms, would be useful in preparing hazard assessments. Another area for future research is the impact of drilling fluids that contain diesel oil, or chemicals used in place of diesel oil, on structure and function of benthic communities.

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LIST OF ABBREVIATIONS AND SYMBOLS

AEA	Adaptive Environmental Assessment
API	American Petroleum Institute
bbl	Barrel(s); 42 U.S. gallons or 159 liters
cm	Centimeter
LC50	Concentration of Test Material Lethal to 50% of Test Organisms for Specified Exposure Period
°C	Degrees Celsius
EC50	Concentration of Test Material Effective in Producing a Defined Response in 50% of Test Animals
EPA	U.S. Environmental Protection Agency
ERL/GB	Environmental Research Laboratory, Gulf Breeze
FAA	Free Amino Acids
g	Gram
h	Hour(s)
LP	Liquid Phase
ℓ	Liter
m	Meter
µg	Microgram
µm	Micrometer
mg	Milligram
mℓ	Milliliter
mm	Millimeter
min	Minute(s)
MAF	Mud Aqueous Phase
NBS	National Bureau of Standards
NOAA/NMFS	National Oceanic and Atmospheric Administration/ National Marine Fisheries Service

NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NTIS	National Technical Information Service
NEA	New England Aquarium
NPS	Ninhydrin-Positive Substance
OCS	U.S. Outer Continental Shelf
ppb	Parts Per Billion (micrograms per liter or nanoliters per liter)
ppm	Parts Per Million (milligrams per liter or microliters per liter)
PESA	Petroleum Equipment Suppliers Association
ppg	Pounds Per Gallon
SAI	Science Applications, Inc.
STACH	Short-Term Aerated Coral Habitats
SP	Solid Phase
SPP	Suspended Particulate Phase
TOC	Total Organic Carbon
UV	Ultraviolet
WM	Whole Mud
yr	Year(s)

INTRODUCTION

The Environmental Research Laboratory at Gulf Breeze, Florida (ERL/GB), a part of the Office of Research and Development of the U.S. Environmental Protection Agency (EPA), has carried out a research program since 1976 to evaluate the potential impact of drilling fluids on the marine environment. The purpose of this report is to present a summary of in-house and extramural research results to date (June 1984), and to discuss these results in the form of a hazard assessment.

The drilling fluid research program was conceived in 1975 in response to the King-Muir report (King and Muir, 1974) which examined the environmental issues associated with more rapid development of oil and gas resources in offshore areas of the United States. The program was given added importance by the need for a technical data base to support issuance of National Pollutant Discharge Elimination System (NPDES) permits, as required by section 403 of the Clean Water Act. The Outer Continental Shelf Lands Act extended federal authority to the subsoil and seabed of the Outer Continental Shelf. Specifically, all marine discharges are required to be permitted under NPDES. The permits must be issued in compliance with guidelines written pursuant to section 403(c) of the Clean Water Act. Personnel from EPA headquarters and regional offices utilize research findings such as those presented in this report as part of the permitting process (EPA, 1982).

Two individuals have directed the ERL/GB program from 1976 to date. Dr. Norman Richards designed the program in 1976, was instrumental in awarding the first research grants in 1977, and is responsible for the majority of the peer-reviewed articles produced by the program and summarized in a following section. Dr. Thomas W. Duke served from 1981 until the present and coordinated the testing of used (spent) and generic drilling fluids and the Adaptive

Environmental Assessment (AEA) Workshops discussed later in this report; however, Thomas W. Duke and Patrick R. Parrish assume full responsibility for the contents of this report.

We present here (1) a brief discussion of the uses and characteristics of drilling fluids; (2) the results of the ERL/GB research program, including a review of scientific articles resulting from research funded by the program, a discussion of the characteristics and toxicity of used drilling fluid samples from the Gulf of Mexico, the results of laboratory tests with generic drilling fluids, a discussion of environmental concentrations, and a presentation of AEA and other models as a means of synthesizing the data accumulated in this program; (3) recent reviews and reports; and (4) conclusions.

USES AND CHARACTERISTICS OF DRILLING FLUIDS

Drilling fluids (also called muds) are essential to the rotary drilling processes used in exploratory and production wells on the U.S. Outer Continental Shelf (OCS). These fluids are forced through the hollow drill pipe and attached rotating bit and returned to the surface through the annular space between the drillstring and the borehole or casing (National Research Council [NRC], 1983). As the fluid returns to the surface, it brings sand, crushed rock, and cuttings produced by the bit and serves several other important functions, such as cooling and lubricating the drill string and bit, maintaining cuttings and other solids in suspension during interruptions in drilling, coating the bore with an impermeable cake to prevent fluid loss, reducing corrosion, and transmitting hydraulic power to the bit. Detailed information on the functions of drilling muds can be found in McGlothin and Krause (1980) and NRC (1983).

To perform the many functions mentioned above, drilling fluids contain a heterogenous mixture of chemicals and other ingredients. The exact formulation depends upon the substrate through which the drilling is taking place, depth of the well, and particular functions of the fluid required at that time. Consequently, there is no "typical" drilling fluid. Some of the basic components of drilling fluids (Table 1) and the relative concentrations are presented by Perricone (1980). Barite, bentonite, lignite, and lignosulfonate comprise about 90% of the materials used in drilling fluids. Barite, a naturally occurring mineral containing barium sulfate, is used to increase the density of the fluid and is the most commonly used weighting agent. Sodium bentonite, attapulgite, and other clays are used to thicken the drilling fluid. Thus, the clays provide viscosity to aid in the removal of drill cuttings from the borehole and improve the wall cake on the borehole. The lignosulfonates are used to ensure that the fluid remains "fluid" and

TABLE 1. Some chemical ingredients in drilling fluids[1]

Ingredient	Use
Barite	Weighting Agents and Viscosifiers
Bentonite	
Attapulgite	
Sodium Tetraphosphate	Dispersants and Thinners
Modified Tannin	
Chromium Lignosulfonate	
Calcium Lignosulfonate	
Lignite	
Starch	Fluid Loss Reducers
Cellulose	
Detergents	Lubricants and Emulsifiers
Non-ionic Emulsifier	
Processed Hydrocarbons including Diesel Oil	
Aluminum Stearate	Defoamers, Bacteriacides
Paraformaldehyde	
Sodium Chromate	Corrosion Inhibitor
Sodium Hydroxide	pH Control
Potassium Hydroxide	pH Stability

[1] After Perricone (1980).

does not become too viscous and completely gel. These deflocculants, therefore, permit the use of clays to enhance viscous properties, but avoid the problems of "thick" mud, which include increased pressure, excessive pump pressure, and poor bit-cleaning properties. Chrome lignosulfonates are the most commonly used deflocculants because of their capacity to function at high temperature and high concentrations of soluble salts. Specialty additives, including items such as biocides to control microorganisms and diesel or other oils to increase lubricity, may be added under use conditions. NRC (1983) presents data on the amounts and kinds of metals, additives, and other selected components of drilling fluids.

EPA (1983) has approved the following types of drilling fluids for use in offshore drilling activities in some recent permits: seawater/freshwater/potassium/polymer, seawater/lignosulfonate, nondispersed, lime, spud, seawater/freshwater gel, lightly treated lignosulfonate freshwater/seawater, and lignosulfonate freshwater. The components of these fluids, without additives, are shown in Table 2. The maximum allowable concentration of ingredients, in pounds per barrel, is specified for each drilling fluid. These generic muds have been tested for toxicity to selected marine organisms by private (Ayers et al., 1983) and government (Duke et al., 1984) laboratories.

As stated previously, Section 403(c) of the Clean Water Act requires knowledge about the potential degradation of the environment from the release of drilling fluids from drilling rigs and platforms. This in turn requires knowledge of the environmental concentrations of the fluids and the effect of these concentrations on the biota. This project has sponsored research in both the fates and effects of the drilling fluids in the marine environment. Also, several models were prepared in an attempt to "bound" the data available and at least point the way to predictive estimations of impact.

TABLE 2. Constituents of eight generic drilling muds[1]

1. Seawater/Freshwater Potassium/Polymer Mud	Maximum allowable concentration (Pounds/barrel)
KCl	50
Starch	12
Cellulose polymer	5
Xanthum gum polymer	2
Drilled solids	100
Caustic	3
Barite	450
Seawater or freshwater	As Needed
2. Seawater/lignosulfonate mud	
Attapulgite or bentonite	50
Lignosulfonate, chrome or ferrochrome	15
Lignite, untreated or chrome-treated	10
Caustic	5
Barite	450
Drilled solids	100
Soda ash/sodium bicarbonate	2
Cellulose polymer	5
Seawater	As Needed
3. Lime Mud	
Lime	20
Bentonite	50
Lignosulfonate, chrome or ferrochrome	15
Lignite, untreated or chrome-treated	10
Caustic	5
Barite	180
Drilled solids	100
Soda ash/sodium bicarbonate	2
Seawater or freshwater	As Needed
4. Nondispersed mud	
Bentonite	15
Acrylic polymer	2
Barite	180
Drilled soilds	70
Seawater or freshwater	As Needed

(continued)

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[1] EPA (1983).

TABLE 2. Continued

5. Spud Mud	
Lime	1
Attapulgite or bentonite	50
Caustic	2
Barite	50
Soda ash/sodium bicarbonate	2
Seawater	As Needed
6. Seawater/Freshwater Gel Mud	
Lime	2
Attapulgite or bentonite	50
Caustic	3
Barite	50
Drilled solids	100
Soda ash/sodium bicarbonate	2
Cellulose polymer	2
Seawater or freshwater	As Needed
7. Lightly treated lignosulfonate freshwater/ seawater mud	
Lime	2
Bentonite	50
Lignosulfonate, chrome or ferrochrome	6
Lignite, untreated or chrome-treated	4
Caustic	3
Barite	180
Drilled solids	100
Soda ash/sodium bicarbonate	2
Cellulose polymer	2
Seawater to freshwater ratio	Approx. 1:1
8. Lignosulfonate freshwater mud	
Lime	2
Bentonite	50
Lignosulfonate, chrome or ferrochrome	15
Lignite, untreated or chrome-treated	10
Caustic	5
Barite	450
Drilled solids	100
Soda ash/sodium bicarbonate	2
Cellulose polymer	2
Freshwater	As Needed

ERL/GB DRILLING FLUIDS RESEARCH PROGRAM

A. ERL/GB DRILLING FLUIDS RESEARCH PROGRAM PUBLICATIONS

A review of selected publications produced by the ERL/GB research program follows; most of the literature was peer-reviewed and is available through EPA's Center for Technical Information or the National Technical Information Service (NTIS). It should be noted that various investigators used different methods to prepare the drilling fluid-in-seawater mixture that was the test material. Some added whole drilling fluid to seawater based on volume:volume measurements, whereas others prepared a stock solution and made dilutions of the fluid-in-seawater slurry to prepare the test material. The units reported here are stated only as parts per billion (ppb), ppm, or parts per thousand (ppt) without regard for the method of test material preparation. Also, drilling fluids of various types and from several sources were used by different investigators. For example, some tests were conducted with used fluids from a well in Mobile Bay, Alabama, even though these fluids were intended for land disposal because of the State of Alabama's permit requirements. However, an incident at a nearby Mobile Bay well in 1982 resulted in the release of drilling fluids into the bay. Such a situation demonstrates the need to obtain toxicity data with aquatic organisms and drilling fluids that are not permitted or intended for disposal in water, especially when the drilling site is in an aquatic environment. Drilling fluids from Jay, Florida, were from a land-based drilling operation. The reader can obtain specifics from the paper(s) of interest.

Corals

Krone and Briggs (1980) and Krone (1981) exposed *Madracis decactis* corals to 100 ppm of used drilling fluid from Mobile Bay, Alabama, spiked with 0, 3, or 10 ppm of ferrochrome lignosulfonate, a commonly used drilling fluid component. There was a concentration-response relationship for the rate of oxygen consumption and ammonium excretion during the first week of exposure, followed by a rate decrease, a secondary increase, and a leveling-off to near-initial rate at the end of the second week of exposure. All exposed corals reduced their polyp expansion behavior, but only two individual coral heads (of the 12 exposed) showed mass polyp mortality. When exposure ended and corals were placed in fluid-free seawater, respiration and excretion of surviving corals remained low and steady and their polyp activity returned to normal within 48 hours.

Thompson and Bright (1980) exposed seven species of coral to each of three concentrations of a used drilling fluid from offshore Louisiana. Adverse effect, determined with serial closeup photography, was defined as the percentage of polyps retracted. *Montastrea annularis*, *Agaricia agaricites*, and *Acropora cervicornis* were killed by exposure to 1,000 ppm drilling fluid; *A. cervicornis* survived in 1,000 ppm in a replicate test, however. All corals except *Dichocoenia stokesii* and *Porites divaricata* showed significant polyp retraction in 100 ppm drilling fluid. *P. divaricata* was affected in 316 ppm but *D. stokesii* was not affected in any concentration.

The effects of a used drilling fluid from Mobile Bay, Alabama, on the reef coral *Montastrea annularis* were studied by Szmant-Froelich et al. (1982). There were no significant effects in 1 and 10 ppm drilling fluid during a 6-week exposure, but corals exposed to 100 ppm drilling fluid had significantly reduced calcification and respiration rates, gross photosynthesis, nitrate uptake rate, and feeding responses. The rate of ammonium uptake was significantly increased. Several of the 100 ppm-exposed corals died before the end of the study.

Dodge (1982) investigated the effects of a used drilling fluid from Jay, Florida, on the reef-building coral *Montastrea annularis* and found that 100 ppm significantly depressed linear increase of the skeleton (extension rate) and fossa length. Long-term (>6 weeks) exposure to 100 ppm also impaired coral skeletal growth and possibly interfered with sediment rejection capability.

Two species of corals, Montastrea annularis and Acropora cervicornis, were used by Szmant-Froelich (1983) to test a used drilling fluid from Jay, Florida. Exposure to 100 ppm for periods from two days to seven weeks caused significant effects on several physiological conditions -- calcification rate, respiration rate, photosynthesis rate, nutrient uptake rate, and normal feeding behavior.

Kendall et al. (1983) monitored the health of the coral Acropora cervicornis by measuring calcification rate, soluble tissue protein concentration, and total ninhydrin-positive substance (NPS) after 24 hours (h) of exposure to 25 ppm, 50 ppm, 100 ppm, and 500 ppm used drilling fluid from Mobile Bay, Alabama. Calcification rate dropped significantly in concentrations of 25 ppm, 50 ppm, and 100 ppm, and soluble tissue protein was significantly less in the growing tip in all drilling fluid concentrations. Total NPS dropped significantly in 100 ppm and 500 ppm, and extensive zooxanthellae loss was observed in the highest concentration. Equivalent concentrations of kaolin [to produce turbidity] caused little effect. This suggested that the adverse effects to the coral were caused by some toxicant in the drilling fluid and not by turbidity alone. The authors cautioned against the use of protein or other tissue components for determining normalcy of corals.

The effects of drilling fluid on the physiological status and microbial infection of Montastrea annularis were studied by Parker et al. (1984) by continuously exposing corals to 1 ppm, 10 ppm, or 100 ppm of a used drilling fluid from Jay, Florida, in flowing seawater for 6 weeks. Coral fragments were then extracted and chemical analyses performed. Three biochemical measures -- diacyl phospholipids, plasmalogen phospholipids and free amino acids --

showed significant exposure-induced sublethal effects and the authors suggested that biochemical indicators may be useful as sensitive markers for pollution-induced changes in corals.

Oysters

Powell et al. (1982) monitored certain physiological changes in eastern oysters (*Crassostrea virginica*) to assess the effects of four stress-inducing agents, one of which was "drilling effluents." The authors found that cysteic acid, glutamic acid, and alanine concentrations in the gill tissue were elevated after a 2-day exposure to 4 ppt drilling effluent. After 5 days of exposure, however, a significant decrease in most amino acids occurred, the total free amino acid (FAA) pool decreasing by 50%. The use of the FAA pool as a monitoring device for stress in marine organisms was suggested.

Scallops

Hamilton (1981) developed an electronic method for monitoring the shell movements and water pumping of bivalve molluscs. He used the method to test the effects of a used drilling fluid and two components, barite and lignosulfonate, on bay scallops (*Argopecten irradians*), and found that exposure to drilling fluid concentrations $\geq$ 400 ppm caused significantly more valve closures; concentrations $\geq$ 200 ppm caused significantly greater cumulative magnitude of valve closures. There was no concentration-response relationship for the components.

The effects of a used drilling fluid and three fluid components on behavior of bay scallops were studied by Hamilton et al. (1981) by using the methods discussed above. The authors concluded that (a) a drilling fluid produces opposite effects at different concentrations; (b) a clear concentration-response relationship does not exist for the components tested (barite, lignosulfonate, and calcium carbonate); and (c) whole drilling fluid has a different effect than its major constituent (barite) and the two other components tested.

Shrimp

Conklin and Rao (1982) conducted tests with two dithiocarbamate formulations (Aquatreat® DNM-30 and Busan® 85), both of which are used as biocides in drilling fluids, to determine their toxicity and effect on limb regeneration of grass shrimp (Palaemonetes pugio). The 96-h LC50 was 127 ppb for Aquatreat and 49 ppb for Busan, and concentrations that inhibited limb regeneration after four days of exposure were 43 ppb and 3.8 ppb, respectively. Neither formulation altered the duration of time to molting, however.

Conklin et al. (1983) tested samples of used drilling fluids that were collected during a single well-drilling operation in Mobile Bay, Alabama. For molting grass shrimp, the 96-h LC50's were from 360 ppm to 14,500 ppm. Although chromium concentrations were high in several of the samples, there was a low correlation between the chromium concentration and toxicity. Because chemical analyses showed that the drilling fluid samples contained # 2 fuel oil-like petroleum hydrocarbons, the authors attributed the toxicity of the samples to the petroleum hydrocarbon content.

Doughtie et al. (1983) induced cuticular lesions in grass shrimp by exposing them to hexavalent chromium. Although there was a concentration-effect relationship for loss of limbs after 3 weeks of exposure, the number of shrimp with cuticular lesions did not increase as chromium concentrations increased. The authors reported the results of histological and ultrastructural examination of the lesions.

Lobsters

Derby and Atema (1981) used extracellular neurophysiological recording techniques to measure the effects of two used drilling fluids on the normal activity of walking leg chemosensory neurons of American lobsters (Homarus americanus). Exposure of lobster legs for 3-5 min to 10 ppm and

100 ppm altered responses to food odors 29% and 44%, respectively. Not all chemoreceptors were inhibited by the drilling fluids, however, because responses to feeding stimuli were recorded from the legs of lobsters that had been exposed to drilling fluid for 4 to 8 days before the neurophysiological measurements.

Capuzzo and Derby (1982) conducted acute lethality and sublethal physiological tests with five drilling fluids and American lobsters. The 96-h LC50's were from 74 ppm to 500 ppm, and sublethal exposures resulted in reduction of growth rate, molting frequency, respiration rate, feeding rate, and growth efficiency. The authors stated that it is primarily the chemical effects and not the physical features of the drilling fluids that were responsible for the detrimental effects on lobsters. They suggested that the diesel fuel content of the fluids contributed to toxicity (even though no direct correlation between diesel concentration and toxicity could be made), and that phenol and metals may also have contributed to toxicity of the drilling fluids.

Atema et al. (1982) studied the effects of drilling fluids on various aspects of American lobster behavior directly related to survival in the field. Water-column (chemical) toxicity was manifested by feeding and molting delays, severe delays in shelter construction, increased walking and swimming, unprovoked tail flipping, and lethargy. Substrate cover by drilling fluids (physical effect) caused delays in shelter construction and lower quality of burrows constructed. The toxicity of the five used drilling fluids ranged from lethality to adult lobsters within hours to no effect on post-larval stages.

Atema et al. (1982) conducted experiments with American lobsters and #2 fuel oil (diesel) to determine the oil concentrations that caused behavioral abnormalities and inappropriate responses to selected stimuli. Concentrations of oil from 0.1 to 1.0 ppm adversely affected lobsters, and the authors hypothesized that the behavioral abnormalities observed could lead to lack of feeding and subsequent population decline.

Crabs

Bookhout et al. (1982) determined the range of concentrations of the mud aqueous phase (MAF) and the suspended particulate phase (SPP) of a low-density, lignosulfonate-type drilling fluid with ferrochrome added that would affect swimming behavior, survival, and duration of development of mud crabs (*Rhithropanopeus harrisii*) and blue crabs (*Callinectes sapidus*). Survival of mud crabs from hatching to megalopa and on to the 1st crab stage was $\geq$ 90% in the control, and in MAF and SPP concentrations ranged from 5% (5,000 ppm) to 100% (100,000 ppm). No blue crab larvae developed to the 1st crab stage in 100% MAF or SPP. The authors also studied the effects of hexavalent chromium (Cr^{+6}) on larval crab development. Mud crabs were adversely affected in 29 ppm NA_2CrO_4 but were not affected in concentrations $\leq$ 15 ppm. Blue crabs were more sensitive. Their development was halted in a 7.2 ppm concentration. Because of the dispersion and dilution of drilling fluids and because the concentration of chromium has been reported to be approximately that of seawater within 100 to 150 meters (m) from the point of discharge of drilling fluids, the authors concluded that it is not probable that chromium in drilling fluids would reduce the population of crab larvae in the area around an oil well.

Sand dollars

The embryos of sand dollars have been used to measure the effects of drilling fluids. Crawford and Gates (1981A and B) tested a lignosulfonate-type used drilling fluid and found that concentrations $\leq$ 100 ppm did not adversely affect the development of *Echinarachnius parma* embryos. Drilling fluid concentrations of 1 and 10 ppt affected fertilization and subsequent embryo development. Crawford (1983) also tested 24 different samples, including a synthetic reference mud, with *E. parma*. He found that no single drilling fluid was typical:

the quantitative effects on embryos varied considerably from one fluid to another; the toxicity of the fluids varied greatly; and the effects on embryonic development varied from one drilling fluid to another.

Sea urchins

Crawford (1983) tested four species of sea urchins (*Strongylocentrotus purpuratus*, *Lytechinus pictus*, and *L. variegatus*) with the 24 different samples and the results for sand dollars described above apply. Schatten et al. (In press) used *L. variegatus* and *Arbacia punctulata* to assess the effects of barium sulfate, a commonly used constitutent of drilling fluids, on sea urchin fertilization and development. In barium sulfate concentrations ≥ 1 millimolar (233 ppm), all the normal fertilization processes were drastically reduced, and at 10 millimolar (2,330 ppm), all fertilization and development were halted.

Fishes

Crawford and Gates (1981A and B) investigated the effects of a used drilling fluid from Mobile Bay, Alabama, on the development of mummichog (*Fundulus heteroclitus*). Embryos were placed in drilling fluid concentrations from 1 ppm to 10 ppt (10,000 ppm) within 1 min after fertilization and maintained for the duration of their development. The drilling fluid appeared to have no measurable effect during the early stages of development but by Day 7 marked effects were observed. Development was delayed and cardiac and body movements were slowed in the higher concentrations. The no-effect concentration was 10 ppm.

Crawford (1983) reported on the results of tests with 24 different samples and mummichog. The used drilling fluid samples were from Mobile Bay, Alabama, Jay, Florida, and unspecified sites. A synthetic drilling fluid was included. Effects on fish embryos were varied, clearly indicating to the author that no single drilling fluid is "typical".

Seven different samples of used drilling fluid from Mobile Bay, Alabama, were tested with young (28±1-day old) sheepshead minnows (Cyprinodon variegatus) in static acute tests by Conklin et al. (1983). The resulting 96-h LC50's (6,300 ppm to 100,000 ppm) were well within the range of previously reported values.

Olla et al. (1981) at the NOAA/NMFS Sandy Hook, New Jersey, Laboratory established behavioral baselines for a common western North Atlantic bottom fish, red hake (Urophycis chuss). In the laboratory, they studied the activity rhythms, agonistic encounters, relation of competition to level [abundance] of food, shelter preference and utilization, and growth rates under simulated field conditions. They conducted a series of tests in which whole used drilling fluid and used drilling fluid that had been "fractionated" by passage through a seawater column were introduced into aquaria and the responses of red hake, sea scallops (Placopecten magellanicus), and sand shrimp (Crangon septemspinosa) were measured. The general behavior (scallop gaping, shrimp burrowing, or fish foraging) of all three species was unaffected by the presence of the drilling fluid at environmentally realistic concentrations (approximately 0.84 kg $m^{-2}d^{-1}$). The level of activity of fish was reduced after the introduction of the fluid, however, and the consumption rates of sand shrimp by hake were lower in the treated aquaria. Olla et al. hypothesized that the fish had more difficulty finding and capturing their prey in the presence of drilling fluid. There were also definite behavioral reactions of all three species in the presence of a plume of drilling fluid. These included agitation, irritation, and escape responses. The hake especially showed a strong escape reaction. Finally, thermocline experiments with larval hake indicated that the early life stages of fishes might be adversely affected by the concentration of drilling fluid constituents in a thermocline.

Community Effects

The effects of drilling fluids on microbiotic and macrobiotic communities were studied.

a. Microbiotic

Cantelmo et al. (1979) determined the effects of barite (94-96% barium sulfate) on the meiofaunal community that was established from flowing, natural seawater in a 10-week study. A sand control and three barite-contaminated treatments were maintained -- 1 part barite/10 parts sand; 1 part barite/3 parts sand; and sand covered with a 0.5-cm layer of barite. Rotifera, Foraminifera, Hydrozoa, Turbellaria, Ostracoda, Polychaeta, and Bivalvia did not exhibit significant differences between the control and barite treatments. The density of Nematoda, Copepoda, and Copepoda nauplii varied with substrate composition, however, and a marked decrease in meiofaunal density was evident in the sand covered with barite. Meiofaunal density in the 1/10 and the 1/3 barite/sand treatments was greater than in the control.

Smith et al. (1982) tested for effects of barite, clay, and three biocides -- Aldacide®, Surflo®, and Dowicide® -- on the biomass and community structure of microbiota that colonized sand over which natural seawater flowed for eight weeks. They observed various changes in microflora and its fatty acid composition, and in biomass and community structure.

White (1982) determined sedimentary microbial biomass, metabolic activity, nutritional status, and community structure by analyzing extractable lipids and hydrolysis products of the lipid-extracted residue. He then used the methods to compare the effects of drilling fluids on communities that colonized in the laboratory and in the field. He found that drilling fluids could significantly modify the biomass and community structure of microbial assemblies, and concluded that the impacts of xenobiotics in the field could be predicted on the basis of laboratory test results.

b. Macrobiotic

Tagatz et al. (1980) assessed the effects of a used drilling fluid from offshore Cameron, Louisiana, and barite, Aldacide, pentachlorophenol, Dowicide G-ST, and Surflo on the development of estuarine macrobenthic communities. The drilling fluid and barite, both tested as a 2- and 5-millimeter (mm) layer over clean sediment, adversely affected all phyla of developing macrobenthos. The effect concentrations (active ingredient in seawater) for the biocides were: pentachlorohenol, 7 ppb; Dowicide, 18 ppb; and Surflow, 18 ppb. The presence of Aldacide at nominal concentrations as high as 273 ppb did not adversely affect macrobiota.

Rubinstein and Rigby (1980) and D'Asaro (1982) reported the results of a study with a microcosm which was initially developed to test dredged materials but which was used to evaluate the effects of used drilling fluid from Mobile Bay, Alabama. Three dilutions of the fluid -- 10 ppm, 30 ppm, and 100 ppm -- were tested with mysids (*Mysidopsis bahia*), eastern oysters *Crassostrea virginica*), and lugworms (*Arenicola cristata*). The criteria for effect in the 100-day study were survival of mysids and lugworms and shell deposition and chemical bioaccumulation in oysters. Settlement of zooplankton in the drilling fluid was also measured. Mysids were not affected. Oyster shell growth was significantly reduced in the 30 ppm and 100 ppm concentrations, and barium, chromium, and lead were significantly bioaccumulated. Lugworms suffered significant ($\geq$23%) mortality in all concentrations. Twenty species were recruited from zooplankton and there was no significant difference in total species harvested between treatments although fewer polychaetes were collected from the 100 ppm concentration.

Tagatz et al. (1982) tested the effects of drilling fluid (seven samples of lignosulfonate-type fluid in eight weeks) from an active exploratory platform in Mobile Bay, Alabama, on the macrobenthic community that developed from planktonic larvae settling from natural seawater. They found the numbers of tunicates, molluscs, and annelids in 50 ppm of the drilling fluid significantly fewer than in the control. Also, the structure of the 50 ppm-exposed communities was different from the control.

As a convenience to the reader, abstracts of most of the papers cited above are contained in Appendix A.

It should be noted that numerous other publications resulted from the drilling fluid research program. Papers not reviewed above, plus manuscripts in preparation, are listed in Appendix B. (Abstracts of some of these papers are also contained in Appendix A.)

Summary

These publications show that a variety of drilling fluids have been tested with many different marine organisms. In some instances, specific constituents of drilling fluids such as chrome lignosulfonate and biocides were tested either alone or after having been added to drilling fluid. In other situations, the whole fluid was evaluated. Responses of the organisms varied from changes in biochemical processes to death and depended upon the kind of drilling fluid or additive and the concentration to which the organisms were exposed.

The purpose of the research program that produced these publications was twofold: (1) to develop protocols for determining the toxicity of drilling fluids to marine organisms, and (2) to develop a data base on the toxicity of drilling fluids and additives to marine organisms. These are not mutually exclusive goals. During the research program, many scientists pioneered methods for determining sublethal and lethal effects of these complex mixtures and at the same time produced valuable toxicity data. For example, results of toxicity tests conducted early in the program indicated that some additives such as biocides and lubricating agents could be very toxic to test organisms. Data from these tests contributed to the removal of pentachlorophenol (PCP), a biocide, from drilling fluids permitted for release on the OCS. Other biocides tested were much less toxic than PCP.

The data generated can also be used as input for construction of models to predict the impact of drilling fluids on the marine environment. When using the data in this manner, one should consider that often it is difficult to directly compare the sensitivity of one organism with another because exposure techniques were not the same and many different drilling fluids were used in the tests.

A survey of the toxicity data reveals gaps in the data base that require additional research. One such gap results because most tests were conducted according to standard toxicity testing procedures with continuous exposure of the organisms for 96 hours. These tests are widely used and yield valuable information, especially when comparing these results with those reported by others. Because of the manner in which organisms are likely to be exposed to drilling fluids released on the OCS, however, additional data are needed from organisms exposed for short periods of times -- minutes and a few hours -- and for long periods of time relative to the life span of the test organisms.

Another area of potential research deals with community studies. The few such studies in the literature are concerned with the impact of drilling fluids on the structure of bottom communities and results are expressed as changes in the numbers of individuals and kinds of species. Information is also needed on the effects of drilling fluids and additives on processes of the communities. Impact of the fluids on flux of nutrients or on rate of microbial degredation may be a more sensitive indicator of effects than changes in structure.

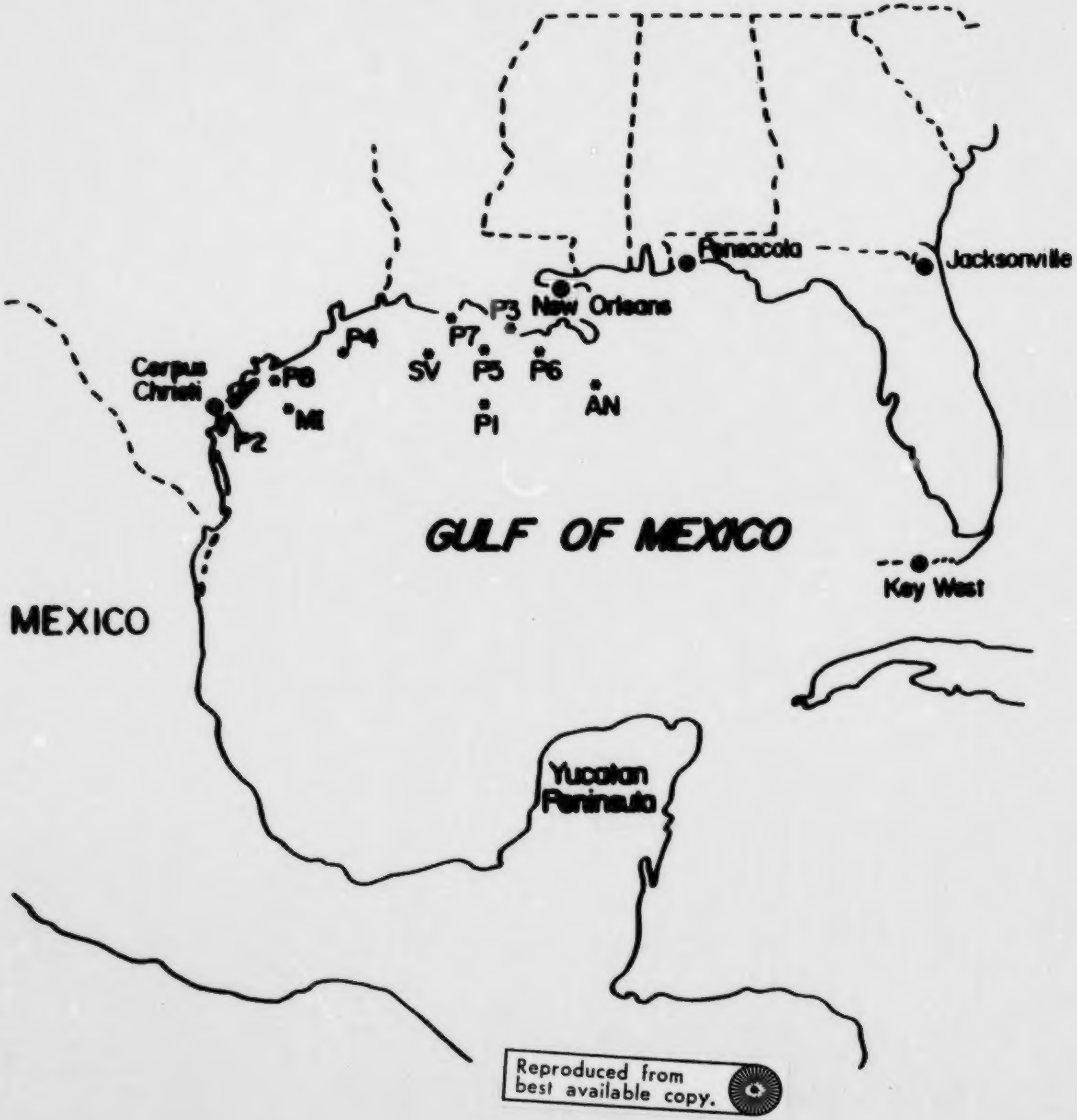
B. CHARACTERISTICS AND TOXICITY OF USED DRILLING FLUID SAMPLES

A cooperative program was conducted to determine the effects on selected marine organisms of used drilling fluids discharged from operating drilling rigs in the Gulf of Mexico. At the beginning of the program, a list of wells of varying depth and geographical location that were using a specific generic mud (for example, seawater lignosulfonate) was supplied to the program officer at ERL/GB by the Petroleum Equipment Suppliers Association (PESA). When a sample was needed, the well from which the sample was to be collected was selected by the program officer based on drilling conditions and well location. Toward the end of the selection period, the muds that were being used less frequently were sampled on a "first appear, first sampled" basis. That is, the first time a desired drilling fluid type was employed in a drilling operation, the sample was taken regardless of well location or depth. The locations and designations of the 11 muds collected by PESA and tested in the project are shown in Figure 1. Also, more detailed information on rig location can be found in Appendix C.

The fluids, collected from appropriate rigs, were separated by PESA into two equal portions; PESA then shipped one sample to ERL/GB and the other to the American Petroleum Institute (API) in Houston, Texas, or to an API contractor. Samples received at ERL/GB were either refrigerated at 4±1 degrees Celsius (°C) or mixed, subsampled, and immediately sent to extramural contractors. Some of the subsampled fluid was also used in toxicity tests conducted at ERL/GB. A flow chart indicating how the samples were distributed is shown in Figure 2.

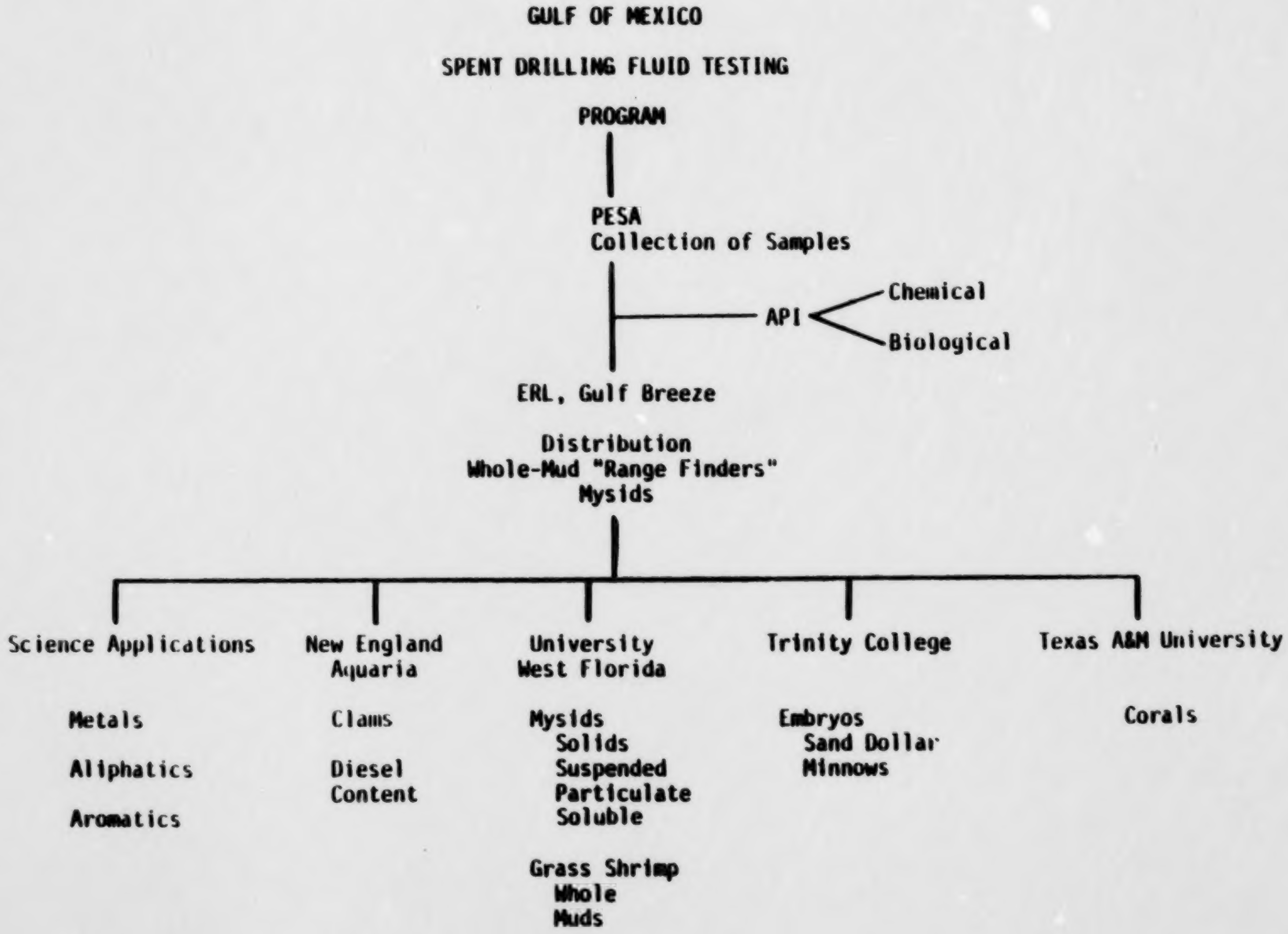
Determinations of the toxicities of the mud samples to selected marine organisms were made by the ERL/GB staff and various extramural investigators. The ERL/GB staff conducted tests to evaluate the effects of whole and three

FIGURE 1. Locations and designations of 11 used drilling fluid samples collected by PESA


Jacksonville
Pensacola
New Orleans
P3
P7
P4
SV
P5
P6
AN
P1
Corpus Christi
P8
MI
P2
GULF OF MEXICO
Key West
MEXICO
Yucatan Peninsula

Reproduced from best available copy.

FIGURE 2. Flow chart of PESA drilling fluid sample distribution and use


GULF OF MEXICO
SPENT DRILLING FLUID TESTING
PROGRAM
PESA
Collection of Samples
API
Chemical
Biological
ERL, Gulf Breeze
Distribution
Whole-Mud "Range Finders"
Mysids
Science Applications
Metals
Aliphatics
Aromatics
New England Aquaria
Clams
Diesel Content
University West Florida
Mysids
Solids
Suspended
Particulate
Soluble
Grass Shrimp
Whole
Muds
Trinity College
Embryos
Sand Dollar
Minnows
Texas A&M University
Corals

phases of drilling fluids on mysids (*Mysidopsis bahia*). Conklin and Rao, University of West Florida, subjected larval grass shrimp (*Palaemonetes intermedius*) to tests with whole muds. The New England Aquarium (NEA) staff tested a variety of organisms, including hard clams (*Mercenaria mercenaria*). NEA also assessed the effect of used drilling fluid on the recolonization of natural, defaunated sediments. Powell, Texas A&M University, exposed corals (*Acropora cervicornis*) to the drilling fluids. Crawford, Trinity College, studied the impact of the fluids on estuarine minnows (*Fundulus heteroclitus*), sand dollars (*Echinarachnius parma*), and sea urchins (*Strongylocentrotus purpuratus*, *Lytechinus pictus*, and *L. variegatus*).

1. Characteristics of used drilling fluids

Chemical analyses of the drilling fluids were performed by Shokes and coworkers, Science Applications, Inc. (SAI) (1984), and by NEA (1984). The SAI group analyzed the fluids for barium, aluminum, cadmium, chromium, copper, and iron as well as aromatic and aliphatic fractions. The NEA staff analyzed the fluids for barium, cadmium, chromium, copper, manganese, lead, and zinc. The two oxidation states of chromium, Cr^{+3} and CR^{+6}, were studied. Also, the NEA group determined concentrations of "diesel" in each of the samples. Although both groups analyzed some of the same metals, their results were not comparable because the drilling fluids were not prepared for analysis in the same manner. For example, SAI prepared liquid and suspended particulate phases according to the standard EPA Region II method (EPA, 1978A) by using 4:1 seawater to drilling fluid ratio and NEA used 0.15 to 3 milliliters (ml) of drilling fluid to 1-2 liters (ℓ) of 0.45-micrometer (μm) filtered seawater. Details of the procedures and extensive tables are contained in the final reports (SAI, 1984 and NEA, 1984).

A summary of the results of the chemical analysis of the drilling fluids is presented in Tables 3 and 4. Analysis of "diesel" content was accomplished by modifying an EPA Environmental Assessment Procedure (EPA, 1978B) and employing chromatographic/mass spectrometric systems and external standards. Quantification was based on measurements of external standards (API #2 fuel oil). The metal analyses utilized instrumental neutron activation for barium and a combination of flame and flameless atomic absorption for the remaining metals. In general, the analysis followed EPA's Methods for Water and Wastewater (EPA, 1979) and Standard Methods (APHA et al., 1980). Organics were measured by capillary column gas chromatography, utilizing flame ionization detection and electron capture.

It is possible to change metal concentrations given in Tables 3 and 4 from dry- to wet-weight basis and to relate the concentrations in suspended particulate and liquid phases to the whole or bulk mud. For each whole drilling fluid sample, heavy metal concentrations are expressed as mass of metal per unit mass of dry sediment (usually micrograms per gram [μg/g]; percentage by weight for Al, Ba, Ca, Fe). Heavy metal concentrations of whole drilling fluid may be changed from dry-weight basis (i.e., μg/g dry mud or percentage by weight) to wet-weight values (i.e., μg/g wet fluid) by using the following conversion:

$$\mu\text{g metal/bulk drill fluid} = \frac{\mu\text{g metal}}{\text{g dry mud}} \cdot \frac{\text{g dry mud}}{\text{g bulk drilling fluid}}$$

$$= \frac{\mu\text{g metal}}{\text{g dry mud}} \cdot (1-[\text{percent } H_2O/100])$$

TABLE 3. Hydrocarbon concentrations of drilling fluid samples

MUD	"DIESEL"[1] (mg/g)	WHOLE MUD[2] Aliphatic (mg/l)	WHOLE MUD[2] Aromatic (mg/l)	SUSPENDED PARTICULATE PHASE[3] Aliphatic (mg/l)	SUSPENDED PARTICULATE PHASE[3] Aromatic (ug/l)	SUSPENDED PARTICULATE PHASE[3] Polar Fraction (ug/l)	LIQUID PHASE[4] Resolved (mg/l)	LIQUID PHASE[4] Unresolved (mg/l)
MIB	0.19	34.5	22.13	0.046	0.073	25.0	0.358	0.813
AN31	1.18	604	292.5	0.325	0.089	497	0.136	1.24
SV76	3.59	1,430	496	3.52	0.912	1,630	0.920	6.63
P1	9.43	6,900	1,600	14.2	5.53	950	0.358	0.603
P2	2.14	1,052	275.6	0.694	0.426	1,380	0.005	0.008
P3	3.98	7,230	675	15.8	2.86	1,120	1.09	6.49
P4	0.67	680	209	0.462	0.442	147	0.002	0.011
P5	1.41	930	390	3.74	1.37	165	0.166	1.16
P6	0.10	22.4	11	0.039	0.038	13.6	0.043	0
P7	0.50	101.3	40.0	0.063	0.030	478	0.175	0
P8	0.56	474	250.9	1.37	1.71	836	0.161	2.42

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[1] Values obtained by gas chromatographic/mass spectrometric analyses and external standards (NEA, 1984).

[2] Total resolved and unresolved (SAI, 1984).

[3] Total resolved and unresolved (SAI, 1984).

[4] SAI (1984).

TABLE 4. Metals content of drilling fluid samples[1]

	MIB			AN31			SV76			P1		
ELEMENT	WM[2]	SP[3]	LP[4]	WM	SP	LP	WM	SP	LP	WM	SP	LP
Al	5.19%	473	0.026	3.74%	1,206	0.079	0.61%	482	0.030	1.01%	555	0.047
Ba	9.85%	13.9	0.409	21.8%	15	0.469	37.5%	12.5	0.407	36.9%	10.7	0.460
Cd	0.387	0.007	0.001	2.38	0.076	0.005	1.62	0.315	0.009	1.85	0.26	0.004
Ca	4.39%	-	-	1.57%	-	-	0.82%	-	-	0.86%	-	-
Cr	337.0	5.76	0.338	774	828	1.15	1,345	457	43.6	814	221	3.34
Cu	23.4	0.349	0.000	33.6	2.56	0.098	86.1	15.0	1.27	62.3	15.9	0.119
Fe	4.31%	546	0.295	2.68%	1,565	1.09	3.63%	1,975	1.85	3.44%	1,566	1.49
Pb	135	1.41	0.011	142	1.20	0.040	151	18.4	0.161	129	13.3	0.093
Sr	510	-	-	538	-	-	536	-	-	303	-	-
Zn	161	276	0.001	247	14.5	0.526	495	93.1	0.487	410	52.5	0.075

(continued)

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[1] From SAI (1984).

[2] WM = Whole Mud Concentrations expressed as µg/g dry weight, unless otherwise indicated.

[3] SP = Suspended Particulate Concentrations expressed as µg/g wet weight, unless otherwise indicated.

[4] LP = Liquid Phase Concentrations expressed as µg/g wet weight, unless otherwise indicated.

TABLE 4. Continued[1]

ELEMENT	P2			P3			P4			P5		
	WM[2]	SP[3]	LP[4]	WM	SP	LP	WM	SP	LP	WM	SP	LP
Al	0.76%	793	0.009	1.30%	661	0.132	1.56%	1,083	2.41	0.71%	376	0.354
Ba	37.2%	8.05	3.32	35.1%	22.9	0.813	48.7%	11.7	10.7	37.5%	15.9	1.04
Cd	11.8	2.38	0.007	2.10	0.053	0.002	8.27	3.06	0.004	2.34	0.075	0.003
Ca	0.65%	-	-	0.74%	-	-	0.18%	-	-	0.57%	-	-
Cr	483	237	0.896	459	138	2.60	532	197	41.8	187	34.6	0.513
Cu	39.7	11.8	0.019	90.4	11.1	0.243	32.7	12.3	0.059	126	10.6	0.373
Fe	0.70%	1,784	1.27	5.67%	1,810	1.84	1.15%	2,896	32.4	7.63%	1,996	1.60
Pb	291	40.6	0.046	100	10.2	0.104	221	28.2	1.56	104	9.07	0.054
Sr	226	-	-	383	-	-	207	-	-	346	-	-
Zn	2,064	338	0.007	439	41.8	0.140	1,384	476	0.804	175	27.5	0.007

(continued)

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[1] From SAI (1984).

[2] WM = Whole Mud Concentrations expressed as μg/g dry weight, unless otherwise indicated.

[3] SP = Suspended Particulate Concentrations expressed as μg/g wet weight, unless otherwise indicated

[4] LP = Liquid Phase Concentrations expressed as μg/g wet weight, unless otherwise indicated.

TABLE 4. Continued[1]

ELEMENT	P6			P7			P8		
	WM[2]	SP[3]	LP[4]	WM	SP	LP	WM	SP	LP
Al	5.10%	1,012	0.021	4.47%	1,010	0.011	0.68%	398	0.026
Ba	18.8%	15.8	0.134	21.0%	19.4	0.328	3.00%	15.9	0.302
Cd	10.5	0.556	0.017	0.21	0.018	0.001	0.410	0.024	0.002
Ca	0.19%	-	-	0.46%	-	-	1.54%	-	-
Cr	41.8	1.06	0.227	502	35.6	0.436	480	133	11.0
Cu	35.1	2.18	0.002	15.6	0.932	0.021	3,448	16.0	0.268
Fe	2.51%	1,243	0.108	2.25%	1,001	0.288	1.25%	802.0	1.39
Pb	210	10.2	0.003	92.1	1.45	0.004	48.3	5.20	0.199
Sr	120	-	-	258	-	-	1,401	-	-
Zn	1,755	80.4	0.007	144	6.30	0.007	144	22.6	0.185

[1] From SAI (1984).

[2] WM = Whole Mud Concentrations expressed as µg/g dry weight, unless otherwise indicated.

[3] SP = Suspended Particulate Concentrations expressed as µg/g wet weight, unless otherwise indicated

[4] LP = Liquid Phase Concentrations expressed as µg/g wet weight, unless otherwise indicated.

A water content value (expressed as weight percent) for each sample (if reported) is given below.

Fluid	Range of Water Content (%)[1]
MIB	69.5 - 75.8
AN31	49.9 - 66.7
SV76	27.3 - 58.1
P1	33.8 - 59.9
P2	30.0 - 58.8
P3	26.8 - 57.8
P4	33.5 - 60.2
P5	26.3 - 57.5
P6	71.5 - 78.1
P7	57.0 - 69.9
P8	27.3 - 58.1

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[1] From NEA (1984) and SAI (1984).

To express as mass of metal/volume of whole mud requires an estimate of bulk fluid density which can be made by:

$$\text{bulk mud density (g/ml)} = \frac{\text{g bulk drilling fluid}}{\text{ml } H_2O + \text{ml dry mud}}$$

$$\text{where ml } H_2O = \text{g } H_2O/\text{density } H_2O$$

$$= \frac{\% H_2O \text{ g}/}{100 \quad\quad /}(1 \text{ g/ml})$$

$$\text{ml dry mud} = \text{g dry mud/density dry mud}$$

$$= \frac{(100\text{-}\%H_2O) \quad \text{g}/}{100 \quad\quad\quad /}(2.5 \text{ g/ml})$$

Conversion from mass of bulk drill fluid (wet) to volume of bulk drill fluid can then be made by using the following equation:

$$\text{volume bulk drilling fluid} = \frac{\text{mass bulk drilling fluid}}{\text{density bulk drilling fluid}}$$

This last conversion from mass of metal/mass of bulk drilling fluid to mass of metal/volume of bulk drilling fluid can be used to relate the mass/volume concentrations of metals in the suspended particulate and liquid test phases (which were produced by adding measured volumes of drilling fluid to form seawater suspensions) to the concentrations in each original bulk fluid.

All hydrocarbon concentrations, except "diesel," are expressed in mass of component/volume of bulk drilling fluid (or volume of final test phase). As just described for heavy metal contents, conversions can be made between mass/volume, mass/dry mass, and mass/wet concentrations by using the measured water contents and an assumed dry mud density of 2.5 g/ml.

The variability in the chemical content of drilling fluids is well illustrated by the range of metal concentrations in the fluids tested. For example, the barium content of MIB whole mud, a seawater lignosulfonate fluid, was 9.85% and the content of sample P4, a freshwater lignosulfonate fluid, was 48.7%. Other examples of variability include chromium, 42-1,345 ppm; iron, 0.7 to 7.6%; and zinc, 144 to 2,064 ppm. Barium consistently occurred at the highest concentration and cadmium at the lowest. A comparison of the ranking of the three phases of two of the fluids, P1 and P3, indicates the differential concentration of the metals in the fluids:

P1 Whole Mud

Ba>Fe>Al>Ca>Cr>Zn>Sr>Pb>Cu>Cd

Suspended Particulate Phase

Fe>Al>Cr>Zn>Cu>Pb>Ba>Cd (Ca and Sr undetectable)

Liquid Phase

Cr>Fe>Ba>Cu>Pb>Al>Zn>Cd (Ca and Sr undetectable)

P3 Whole Mud

Ba>Fe>Al>Ca>Cr>Zn>Sr>Pb>Cu>Cd

Suspended Particulate Phase

Fe>Al>Cr>Zn>Ba>Cu>Pb>Cd (Ca and Sr undetectable)

Liquid Phase

Cr>Fe>Ba>Cu>Zn>Al>Pb>Cd (Ca and Sr undetectable)

The shift in relative concentrations of Ba and Cr among the phases is particularly interesting; it was the same for both P1 and P3 although P1 was a seawater lignosulfonate-type and P3, a lime-type mud. High Ba concentrations in whole mud are expected because of the large quantities of barium sulfate added to the fluids. High and variable concentrations of Ba can also be expected in the suspended solids because of the particulate barium sulfate remaining in suspension after the designated 1-hour settling time required to produce the suspended particulate phase. In contrast to Ba, Cr occurred at concentrations less than four other metals in whole mud, less than two others in suspended particulates, but was highest in concentrations in the liquid phase. The relationships among the metal distribution in the various phases in relation to toxicity to various organisms are discussed later in this report.

Investigations at NEA also determined three general types of metal species of certain trace metals -- free ionic form, including inorganic complexes (i.e., chloro, hydroxy, etc.), organically bound metals, and those associated with the particulates. Free metal ion concentrations were determined through equilibrium dialysis separation prior to trace metal analysis. In addition, ultra-violet (UV) absorbance was employed to detect the presence of lignosulfonate or other UV-absorbing organic compounds. Additional experiments were conducted to determine what fraction, if any, of free Cr was present as Cr^{+3}. The concentrations of trace metals were detected by direct current plasma emission spectrometry. (See NEA, 1984, for details of these analyses.)

Because of the potential threat of metal toxicity, bioaccumulation, and food chain magnification of Cr in seawater, the speciation of this element in the liquid phase of six drilling fluids was investigated (NEA, 1984). Free Cr ranged from 0.005 to 0.214 ppm; Cr^{+3}, from 0.014 to 0.026 ppm; and Cr^{+6} (by difference), non-detectable to 0.19 ppm. Most of the Cr present probably was complexed with lignosulfonate. The authors suggested that the lack of toxicity of Cr^{+3} (relative to Cr^{+6}) was due chiefly to its low solubility. However, lignosulfonates can complex Cr^{+3} and increase its solubility, thus increasing potential toxicity. Because (a) rather larger quantities of Cr^{+6} salts are sometimes added to drilling fluids and (b) some of the Cr^{+6} could remain unreacted in fluids where pH is unfavorable for reduction, potential toxicity could be increased, according to the authors.

2. Biological testing at ERL/GB with mysids

Investigators at ERL/GB (Gaetz, Montgomery, and Duke)[1] conducted tests on the effect of the 11 drilling fluids on mysids by using EPA's Region II Method (EPA, 1978A), with some modifications. The method calls for testing the toxicity of liquid and suspended particulate phases of the drilling fluid with mysids and the solid phase with hard clams. In these tests, the solid phase was tested with mysids and two fluids only, chiefly for comparative purposes. The Region II method was employed so that results obtained in this study could be compared with the previously developed data base involving mysids and drilling fluids. Briefly, this method specifies the manner in which the drilling fluid is separated into liquid, suspended particulate, and solid phases and the protocol for conducting the toxicity tests. The bulk or whole mud sample was mixed, subsamples removed, and mixed again in a ratio of 4:1 seawater to drilling fluids. The resulting slurry was mixed for 30 min and allowed to settle for 1 h. At the end of the settling period, the supernatent was withdrawn, centrifuged, and filtered through a 0.45-μm filter. The remaining clear fluid was the liquid phase. The suspended particulate phase was prepared in a similar manner, but was that material remaining in solution after the 1-h settling period. Material that settled from the other two phases was the solid phase. Dissolved oxygen and pH of the drilling fluid samples were controlled during the preparation. Use of the bulk or whole mud was not specified in the Region II method. When whole mud was used, it was added, volume to volume, to the test dishes. The whole mud and solid phase tests differed from the Region II method because no reference sediment was added to the test container before addition of the mud or solid phase.

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According to the Region II method, mysids are exposed to volume:volume concentrations of the liquid and suspended particulate phases of the drilling fluid and seawater for 96 h; 24-h juvenile mysids are subjected to the test phases in three replicates. Temperature of the water is maintained at 20±2°C and dissolved oxygen at approximately 65% of saturation. (An appropriate range-finding test is conducted prior to the definitive test to establish test concentrations). Five test concentrations plus a control are required in the definitive tests and twenty mysids are exposed in each test dish containing one liter of seawater.

In the ERL/GB tests, mysids were exposed to whole mud as well as liquid, suspended particulate, and in two instances, solid phases. The whole mud exposures were conducted primarily to establish definitive toxicity concentrations as guidelines for other participants in the program. These data may also be useful in studies of the impact of drilling fluids when released in shallow (≤20 m) waters where turbulence and mixing processes could result in exposure of organisms to the whole mud. Organisms exposed to discharges from wells in deeper water and more than 100 m from the release site would probably be exposed to other phases of the drilling fluid.

The mysids were more sensitive to the whole mud than to the three individual phases (Table 5). When ranked according to greatest toxicity, sample P1, a lightly treated lignosulfonate fluid, was first and P3, a lime fluid, was second. The LC50 values for five other lignosulfonate-type fluids were near or below 1,000 ppm. These values are generally lower (more toxic) than have been

TABLE 5. Toxicity of used drilling fluids to mysids (*Mysidopsis bahia*)

		96-HOUR LC50[1] (ppm; µl/l)			
EPA MUD CODE	MUD TYPE	WHOLE MUD	LIQUID PHASE	SUSPENDED PARTICULATE PHASE[2]	SOLID PHASE
MIB	Seawater Lignosulfonate	>1,500[3]	NT[4]	NT	NT
AN31	Seawater Lignosulfonate	1,008(541-1,557)[d]	>150,000	NT	NT
SV76	Seawater Lignosulfonate	733(429-888)	>150,000	17,633(15,123-19,835)	>50,000
P1	Lightly Treated Lignosulfonate	26(14-39)	>150,000	1,936(1,641-2,284)	1,456(1,246-2,437)
P2	Freshwater Lignosulfonate	459(301-732)	116,419(111,572-121,476)	18,830(14,068-22,522)	NT
P3	Lime	92(87-98)		726(650-791)	11,304(8,213-1,369,393)
P4	Freshwater Lignosulfonate	>1,500	97,238	27,233(24,791-29,265)	NT
P5	Freshwater/Seawater Lignosulfonate	263(115-379)	>150,000	24,770(11,380-38,362)	>50,000
P6	Low Solids Nondispersed	>1,500	>150,000	>50,000	>50,000
P7	Lightly Treated Lignosulfonate	728(470-1,958)	>150,000	>50,000	NT
P8	Seawater/Potassium/Polymer	>1,500	>150,000	27,137(26,025-28,070)	NT

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[1] Results of probit analyses; 95% confidence limits are in parentheses.

[2] The suspended particulate phase (SPP) was prepared by mixing 1 part drilling fluid with 4 parts seawater. Therefore, these values should be multiplied by 0.20 in order to relate the 1:4 dilution tested to the SPP of the whole drilling fluid.

[3] The toxicity concentrations for the "greater than" values (>1,500, >150,000, >50,000) were arbitrarily selected for these specific tests.

[4] Not tested.

reported for marine organisms in the past (Petrazzuolo, 1981 and Ayers and Sauer, 1983). However, they are comparable to data recently reported by Conklin and Rao (In press). The 96-h LC50's for two other lignosulfonate fluids were 1,500 ppm so the toxicity did not appear to be related to a specific type of fluid.

The liquid phase was the least toxic of all treatments. This is somewhat surprising because mysids are primarily water column organisms and would be susceptible to hydrocarbons and metals in the liquid phase. It is possible that the mechanics of preparing the liquid phase (centrifuging and filtering) caused loss of metals and hydrocarbons. However, mysids were observed to move throughout the water column and into settled muds when tested with whole muds and suspended particulate and solid phases. Even though the liquid phase was the least toxic, the toxicity of the other treatments evidently was not a result of suspended particulates only. For example, exposure to a whole mud sample of P1 resulted in an LC50 of 25 ppm, while 1,500 ppm of fluid P4 did not kill 50% of the animals. The two most toxic fluids in the liquid phase, P2 and P4, were not the most toxic in the other phases.

The toxicity of the suspended particulate phase was less than that of whole mud, but greater than the liquid or solid phase. Values reported in Table 5 under the heading of suspended particulate phase must be multiplied by 0.20 in order to relate the 4:1 ratio of test seawater solution:drilling fluid to the suspended particulate phase of whole fluid. The rank order of toxicity of this phase was different from that of the other treatments. Again, toxicity did not appear to be related to any specific type of fluid.

An inspection of the chemical analyses presented in Table 3 indicates a relationship between the aromatic, aliphatic, and "diesel" content of the fluids and the toxicity to the organisms. Further analysis using Spearman Rank Order

Coefficients (Steel and Torrie, 1980) yields the following significant correlations:

	Chemical Content		
	Aromatic	Aliphatic	"Diesel"
Toxicity			
Whole drilling fluid	-0.79	-0.77	-0.81
Suspended particulate phase	-0.77	-0.89	-0.96

The most toxic fluid, P1, was tested periodically to evaluate the consistency of its toxicity after storage for a long period and after processing for each toxicity test. Accordingly, standard toxicity tests were conducted for about one year and the resulting LC50's are reported below.

Date of Test	96-h LC50 (μl/1) and 95% C.L.	Method of Analysis
4/26/82	15.6(8.1-29.2)	Logit
5/24/82	24.0(14.8-37.3)	Probit
8/18/82	25.5(14.3-39.9)	Probit
8/25/82	12.7(5.6-26.6)	Logit
9/13/82	35.4(24.2-51.6)	Moving Average
9/27/82	53.1(39.3-74.0)	Moving Average
10/11/82	18.7(7.8-36.6)	Probit
10/11/82	45.7(34.5-64.4)	Moving Average
12/07/82	47.1(33.8-63.6)	Moving Average
1/03/83	47.3(20.4-91.6)	Probit
1/10/83	26.1(15.4-37.8)	Moving Average
1/31/83	54.4(37.9-84.7)	Probit
2/28/83	54.7(40.8-77.1)	Moving Average
3/22/83	47.8(34.5-63.2)	Probit
4/05/83	76.1(50.0-100.0)	Binomial
4/06/83	63.6(45.6-86.6)	Probit

An examination of the LC50'S reveals a strong correlation wherein toxicity decreased with time. The decrease could be related to the volatility of the hydrocarbons in the drilling fluid. The fluid used for these tests was placed in a glass jar, wrapped in foil, and maintained at 4±2°C. However, the same sample was removed from the cooler, shaken, and mixed well each time a portion was withdrawn and used in a subsequent test.

3. Tests with grass shrimp

Tests were conducted by Conklin and Rao (in press) to determine the toxicity of the drilling fluids to grass shrimp. The methods for these tests were similar to those used in a previous study (Conklin et al., 1983), except that in the current project, 24-h larvae were exposed to the whole drilling fluid. In one instance, adults were exposed to one of the fluids for comparative purposes.

The drilling fluids were toxic to grass shrimp (Table 6). The grass shrimp were not as sensitive as the mysids, but the relative sensitivity of grass shrimp and mysids to the fluids was similar. As with mysids, no pattern of toxicity due to the fluid type was evident. For example, the toxicity of the lignosulfonate fluids varied from the most toxic, with an LC50 of 142 ppm, to the least toxic, with an LC50 of 35,420 ppm. In the one instance where adult shrimp were tested, the resulting LC50 of 201 ppm was close to the 142 ppm value obtained with larvae.

The investigators conducted additional tests to evaluate the relationship between the "diesel" content of the fluids and the toxicity to grass shrimp. The object of these tests was to compare the toxicity of one of the original samples with a low "diesel" content before and after the addition of API #2 fuel oil standard. Enough API # 2 fuel oil was added to bring the concentration of diesel in the original mud up to 0.9% or the amount of "diesel" present in P1, the most toxic fluid. Also, the API #2 fuel oil was added and mixed to give the same concentration in a reference fluid prepared by the National Bureau of Standards (NBS). After the API #2 fuel oil was added to the fluids, the resulting mixture was separated into two portions. One portion was stored under

TABLE 6. Drilling fluid toxicity to grass shrimp (Palaemonetes intermedius) larvae[1]

Mud	Type	96-h LC50 (95% CL)
MIB	Seawater Lignosulfonate	28,750 ppm (26,332-31,274)
AN31	Seawater Lignosulfonate	2,390 ppm (1,896-2,862)
SV76	Seawater Lignosulfonate	1,706 ppm (1,519-1,922)
P1	Lightly Treated Lignosulfonate	142 ppm (133-153)
P2	Freshwater Lignosulfonate	4,276 ppm (2,916-6,085)
P3	Lime	658 ppm (588-742)
P4	Freshwater Lignosulfonate	4,509 ppm (4,032-5,022)
P5	Freshwater/Seawater Lignosulfonate	3,570 ppm (3,272-3,854)
P6	Low Solids Nondispersed	100,000 ppm ---
P7	Lightly Treated Lignosulfonate	35,420 ppm (32,564-38,877)
P8	Seawater/Potassium/Polymer	2,557 ppm (2,231-2,794)
NBS Reference		17,917 ppm (15,816-20,322)

[1] All tests conducted at 20 ppt salinity and 20±2°C with Day-1 larvae (Conklin and Rao, in press).

refrigeration (4±2°C) and later added to seawater test solutions and used in toxicity tests according to methods previously employed with the original 11 fluids. The other portion was subjected to a hot-roll process by IMCO Services and Dowell Fluids Technology Center. This process, which simulates down-hole temperatures, involves placing the samples in sealed glass jars that are inserted into stainless steel ovens. The jars and contents are rotated about 30 revolutions per min at 65°C for 16 h. After rolling, the samples are cooled, remixed, and refrigerated at 2 to 4°C.

As expected, treatment with API #2 fuel oil increased the toxicity of the fluids. There was no significant difference in toxicity between fluids receiving the fuel oil with or without the rolling process, nor was there any difference in toxicity resulting from the source of the rolling process (Table 7). The P7 fluids were as much as 290 times more toxic after addition of the API #2 fuel oil standard than the original fluid, and the NBS reference fluid was 150 times more toxic with the added fuel oil. The LC50's resulting from exposure to the diesel contaminated fluids were close to the LC50 of P1, the mud that was most toxic and used as a model for the amount of API #2 fuel oil added to the original P7 sample. Since the LC50 for API #2 fuel oil alone is 1.4 ppm, it is toxic enough to cause the increased toxicity.

An examination of the data in Table 7 again indicates a relation between the hydrocarbon content of the fluids and toxicity to grass shrimp. Spearman Rank Order Correlation Coefficients relating those factors are: aromatic, -0.9454; aliphatic, -0.8363; and #2 fuel oil, -0.8818. These values are significant at alpha = 0.05 and demonstrate a strong correlation betweeen hydrocarbon content and toxicity.

4. Tests with clams and recolonization studies

The effects of drilling fluids on the embryonic development of hard

TABLE 7. Toxicity of API #2 fuel oil, mineral oil, and oil-contaminated drilling fluids to grass shrimp (Palaemonetes intermedius) larvae [1]

Materials tested	Oil added (g/ℓ)	Total oil content (g/ℓ)	96-h LC50 & 95% CL[2] (ppm; μℓ/ℓ)
API #2 fuel oil[3]	---	---	1.4 (1.3-1.6)
Mineral oil[4]	---	---	11.1 (9.8-12.5)
P7 mud	None	0.68	35,4000 (32,564-38,877)
P7 mud + API #2 fuel	17.52	18.20	177 (165-190)
P7 mud + API #2 fuel oil (hot-rolled)	17.52	18.20	184 (108-218)
P7 mud + mineral oil	17.52	18.20	558 (466-638)
P7 mud + mineral oil (hot-rolled)	17.52	18.20	631 (580-674)
NBS reference drilling mud	None	0	17,900 (15,816-20,322)
NBS mud + API #2 fuel oil	18.20	18.20	114 (82-132)
NBS mud + API #2 fuel oil (hot-rolled)	18.20	18.20	116 (89-133)
NBS mud + mineral oil	18.20	18.20	778 (713-845)
NBS mud + mineral oil (hot-rolled)	18.20	18.20	715 (638-788)
P1 drilling mud	None	18.20	142 (133-153)

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[1] From Conklin and Rao (In press).

[2] 95% confidence limits computed by using a "t" value of 1.96.

[3] Properties: Specific gravity at 20°C, 0.86; Pour point, -23°C; Visocity, Saybolt, 38°C, 36; Saturates, wt%, 62; Aromatics, wt%, 38; Sulfur, wt%, 0.32.

[4] Properties: Specific gravity at 15.5°C, 0.84-0.87; Flash point, 120-125°C; Pour point, -12 to -15°C; Aniline point, 76-78°C; Viscocity, CST, 40°C, 4.1 to 4.3; Color, Saybolt, + 28; Aromatics, wt%, 16-20; Sulfur, 400-600 ppm.

clams were studied by exposing 1-h old fertilized eggs to liquid and suspended particulate phases of the fluids. Details in methods and procedures for these experiments can be found in NEA (1984). The criterion for effect was a comparison of the percentage of each test group that reached the straight-hinge or "D" stage of development in comparison to control groups. It should be noted that the liquid and suspended particulates were prepared by mixing 0.15 to 3 mℓ of the drilling fluids with 1 ℓ of 0.45-μm filtered seawater. These dilute suspensions of drilling fluids were stirred and allowed to settle at room temperature for either 1 h to produce a suspended particulate phase or for 72 h to produce a liquid phase. After the appropriate settling period, the test phases were collected by siphoning for use in the toxicity tests.

The embryos used in these tests were taken from adult clams that were collected at Cape Cod, Massachusetts, and maintained at NEA. Feeding was provided through continuous harvest of mixed or unialgal cultures of diatoms and other algal species. Conditioned brood stock animals were spawned by conventional methods and fertilization was achieved when the pooled sperm and eggs were mixed and allowed to remain in contact for 1 h.

Since the muds were tested throughout the year by using several batches of brood animals collected at different times during the year, a standard toxic control fluid was tested to allow comparison among tests. A lignosulfonate fluid from a well in Mobile Bay, Alabama, was tested four times during the 15-month test period. The results indicated reproducibility among tests and spawn groups and suggest that the gene pool of the test populataion was sufficiently uniform to allow direct comparison of tests performed at different times.

A summary of the toxicity of both the liquid and suspended particulate phases the drilling fluids to clam embryos is given in Table 8. The suspended particulate phases of fluids P1, P2, and P3 were more toxic than the water-soluble phases of these fluids although the differences in toxicity were not

TABLE 8. Results of continuous exposure (48 h) of 1-h old fertilized eggs of hard clams (*Mercenaria mercenaria*) to liquid and suspended particulate phases of various drilling fluids. The percentage of each test control (n = 625±125 eggs) that developed into normal straight-hinge or "D" stage larvae and the EC50 is given.[1]

Drilling Fluid	Liquid Phase EC50 (uℓ/ℓ)[2]	Control % "D" Stage	Suspended Particulate EC50 (uℓ/ℓ)[2]	Control % "D" Stage
AN31	2,427(2,390-2,463)	88	1,771 (1,710-1,831)	93
MIB	>3,000	95	>3,000	95
SV76	85(81-88)	88	117(115-119)	93
P1	712(690-734)	97	122(89-151)	99
P2	318(308-328)	97	156(149-162)	99
P3	683(665-702)	98	64(32-96)	99
P4	334(324-345)	98	347 (330-364)	99
P5	385(371-399)	98	382(370-395)	99
P6	>3,000	97	>3,000	93
P7	>3,000	97	2,779(2,667-2,899)	93
P8	269(257-280)	93	212(200-223)	93

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[1] From NEA (1984).

[2] EC50 and 95% confidence limits.

as great as those occurring between phases with mysid shrimp. The remaining fluids did show an appreciable difference in toxicity between the two phases. The toxicity of the liquid phase for 8 of 12 fluids, expressed as 48-h EC50's (the concentrations that prevented 50% of the test animals from reaching the straight-hinge stage of development), ranged from 85-712 ppm and the toxicity of the suspended phase for these fluids ranged from 64-382 ppm. The EC50's for the remaining fluids exceeded 2,000 ppm.

The results of these toxicity tests indicate that the clam embryos were very sensitive to both liquid and suspended particulate phases of the test fluids. These organisms were much more sensitive to the liquid phase than the mysids, but this could be because of differences in preparation of the liquid phases. Mysids were exposed to the liquid phase prepared according to the Region II method (EPA, 1978A) that included filtering and centrifuging the 4:1 seawater to drilling fluid mixture. These actions could have driven off more of the volatile fraction of the hydrocarbons in the fluid than the 72-h settling technique.

These studies with clams did not differentiate between effects due to toxicity of the suspended particulates and turbidity alone. NEA (1984) suggested that it is unlikely that turbidity effects could have resulted even in the highest concentrations (3 mℓ/ℓ) of drilling fluids used in these tests. Also, the criterion for effects was failure of test organisms to reach the straight-hinge stage of development relative to controls. Tests were not conducted to determine if this effect was permanent or if only the rate of development was decreased.

According to the Spearman Rank Order Correlation, a significant correlation existed between hydrocarbon concentration and toxicity of the suspended particulate phase (aliphatic, -0.91; aromatic, -0.88; and "diesel", -0.87), but there was no significant correlation between liquid phase toxicity and its hydrocarbon concentration.

NEA (1984) also monitored the recolonization of natural, defaunated sediments that contained the soild phase of a used, medium density lignosulfonate drilling fluid. Laboratory and field tests included three treatments: a natural, fine-grained defaunated sediment was the control; the drilling fluid soild phase mixed with the natural sediment was the homogeneous treatment; and the solid phase deposited as a surface layer over the natural sediment was the surface treatment. Natural seawater flowed over the treatment sample containers in the laboratory and, in the field, the sample containers were placed in natural seawater.

Based on three parameters -- number of individuals, number of species, and ratio of numbers of species and individuals -- used for statistical analyses, the drilling fluid solid phase affected recolonization when layered on the surface of the natural sediment but not when mixed homogeneously with the sediment. The reduced numbers of individuals in the surface treatment could have been caused by physical or chemical effects of the solid phase, but the former is more likely, according to the authors, because (a) if the effect was chemical one would expect fewer individuals in the homogeneous treatment and this was not the case, and (b) chemical analyses of the solid phase showed relatively low concentrations of components expected to be toxic. In both laboratory and field tests, deposition of a new layer of natural detrital material seemed to reduce or reverse the effects of the solid phase surface layer. Effects of the solid phase were no longer obvious after six months of exposure.

5. Tests with corals

The effects of the drilling fluids on the coral *Acropora cervicornis* were evaluated by Powell et al. (1984). A previous study (Kendall et al., 1984) indicated that proper evaluation of toxicity of drilling fluids to corals could not be made without data on recovery capacity. Accordingly, the corals used in these tests were exposed to dilutions of the whole drilling fluid for 24 h and then permitted to recover for 48 h before biochemical measurements were made to determine effects. The methods for conducting the toxicity tests, stress on corals during collection, and statistical procedures can be found in Kendall et al. (1984) and Powell et al. (1984). The test corals were placed on an elevated grid system contained in a plexiglass dome. The domes were then placed on a suitable bottom substrate in the field and solutions of the drilling fluids were flowed into four sealed dome units designated as STACH (short-term aerated coral habitats). Three exposure and one control unit comprised a STACH. Four STACH experiments were conducted -- three with drilling fluids diluted to 25 ppm (volume/volume) and one with the fluids diluted to 50 ppm (volume/volume). After the 24-h exposure period, the sealed domes were removed and replaced by domes with numerous openings to permit the surrounding water to flow freely past the corals, but protect the corals from predators. Four contiguous sections were removed from each coral branch, starting from growing tip and proceeding to the base (labeled A through D, respectively). Calcification rate, protein concentration, polyp number, skeletal weight, and the FAA were measured. Data were normalized to both skeletal weight and polyp number.

An exposure concentration of 25 ppm was chosen because previously cited work indicated that this concentration produced changes in FAA levels after 48 h of recovery. After exposure to the nine fluids in this series of tests, none of the corals exhibited an observable loss in zooanthellae (a visible manifestation of a destructive toxic effect), but corals exposed to fluid P4 suffered substantial loss of protein. Calcification rate decreased significantly only in corals exposed to P1, P4, and P5, and the same three fluids were the only ones to cause relative changes in the FAA pool. Serine-threonine concentrations decreased relative to aspartate-alanine-glutamate in all three cases. In the remaining fluids, any effect could not be distinguished from a general, moderate decrease in FAA pool size.

Effects produced by exposure to the same fluids varied among the experiments, apparently because of extrinsic environmental factors such as cloud cover, sea state, and turbidity. Corals exposed to fluid P4 showed a significant change in calcification rate and protein concentration at the 25 ppm exposure concentration, but a 50 ppm exposure a few days later produced no significant change. Thus, care should be taken when making experiment-to-experiment comparisons. The variability among toxicity concentrations of fluids in tests conducted simultaneously was much less. For example, P4 produced the most toxic effects in two simultaneous tests and P3 was consistently less toxic relative to two other fluids when tested simultaneously in two separate STACH units.

The causative agents for the observed toxicity of the fluids to corals were explored. Previous tests (Kendall et al., 1983) indicated that turbidity was not a causative factor at the concentrations of fluids used in these experiments. Turbidity of the most toxic fluids (P1, P4, P5) was in the same range as that for less toxic fluids. The concentrations of hydrocarbons were greatest in P1 and P3, yet P1 was one of the most toxic and P3 one of the least toxic of the fluids tested. A similar condition existed for chromium content, with no significant correlation between content and toxicity. The data did not demonstrate one general causative agent for all fluids, but indicated the cause for toxicity varied greatly among the fluids.

In summary, Powell et al. (in press) pointed out that the fluids have a wide range of toxicity and none could be considered non-toxic because each exhibited some toxicity. The exposure times and toxic concentrations were above those normally found in the field. Analysis of the data suggested that under normal operating conditions for OCS drilling rigs, effects should be less than those reported, except perhaps near the rig. However, the data also suggested that cumulative effects of short-term exposures might be important because recovery rates, particularly for the FAA pool, were very slow.

It should be stressed that, for corals, recovery data are necessary to accurately assess the effects of drilling fluids because apparent toxic effects measured at the end of an exposure do not agree well with realized toxicity after a 48-h recovery period.[1]

6. Tests with embryos

Tests were conducted by Crawford (1983) to determine the toxicity of the seawater-soluble components of drilling fluids to embryonic development of a fish, a sand dollar, and three sea urchins. Details of techniques employed in these studies and interpretations can be found in Crawford and Gates (1981A and B). Generally, fish embryos were placed in the drilling fluid solution 1 min after fertilization and maintained at specific fluid concentrations for the duration of their development. Events of embryological development that were observed during this time included early cleavage, blastulation, gastrulation, heart development, and hatching. Gametes of sand dollars and sea urchins were obtained by coelomic injection of about 1 mℓ of 0.5 M KCL and fertilization was begun by adding a few drops of 1% sperm suspension to a suspension of eggs in about 100 mℓ of filtered seawater. Embryos were placed in each incubation medium 10 to 15 min after fertilization and remained for four days, the duration of the tests. Events monitored in sand dollar and sea urchin development included hatching of the blastula to a spinning form, development of the prism, and formation of the pluteus.

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[1] Personal communication. Eric N. Powell, Texas A&M University, Department of Oceanography, College Station, Texas 77843.

The drilling fluids were tested according to their dry weights as follows: a homogeneous slurry of the whole fluid sample was prepared; an aliquot was diluted tenfold, then dried and reweighed. Whole drilling fluids were diluted to a concentration of 10 ppt and then stirred for 1 h at room temperature and the resulting suspension was filtered. This stock solution, referred to as 10 ppt, was diluted with seawater to make up other dilutions. The test solutions contained seawater-soluble components and the units, based on dry weight of the fluids, were as follows:

Drilling Fluid	mg/mℓ (ppt)	Dilution at 10 ppt
MIB	367	1:36.7
SV76	1,132	1:113.2
AN31	650	1:65.0
P1	1,064	1:106.4
P2	1,101	1:110.1
P3	1,331	1:113.9
P4	1,139	1:130.0
P5	1,300	1:130.0
NBS Reference	426	1:42.6

Effects of the fluids on fish embryo development were manifested by reduced heart beat rates in the P1 fluid and the NBS reference. Hatching was significantly affected only in the 10 ppt concentration with fluids MIB, AN31, NBS reference, P1, P2, P3 and P4 fluids. Newly hatched fish were most sensitive to the fluids, and many of the fluids at a concentration of 1 ppt disturbed their normal patterns of behavior.

The impact of the drilling fluids on fertilization of treated eggs is shown in Table 9. Data in this table are for concentrations that affected fertilization. With few exceptions, dilutions of the fluids to 100 ppm allowed normal fertilization. These data were not analyzed statistically because generally the effects were all-or-none. Where the effects appeared to be partial, usually only one or two tests were conducted. In those instances where partial effects were observed, calculation of the standard deviation of the mean demonstrated that the effect was significant. The investigator was careful to use only results from gametes whose control rate of fertilization was 95% or greater; reproducibility at this percentage was excellent.

Development of echinoderm embryos also was affected by the drilling fluids (Table 10). A population of embryos was considered adversely affected if the embryos showed less than the control rate of development. The toxicity varied greatly with the type of fluid but there was similarity of effect among species. Only one fluid, SV, showed toxicity if diluted to 10 ppm.

A "worst case" presentation of the data from these tests is made in Table 11. A "safe" concentration is presented that represents a concentration 10% of that having an adverse effect on the most sensitive test system. Also presented is a dilution that is required to reach the safe concentration based on the dry weights of the fluids. The toxicity, as reflected by the amount of dilution required to reach safe concentration, ranged from 3,600- to 1,132,000-fold.

No chemical measurements were made of the seawater-soluble fraction of the drilling fluid used in these tests. However, the relationship between the diesel content of the whole fluid samples and the dilution factor required for a safe concentration was significant, according to a Spearman Rank Order Correlation Coefficient of -0.74.

TABLE 9. Effects of drilling fluids and components on echinoderm egg fertilization[1].

Drilling Fluid	Concentration[2]	% Fertilization of treated eggs[3]	
		E. parma	*S. purpuratus*
SV76	100 ppm	100 (1)	84 (5)
	1 ppt	94 (1)	0 (5)
	10 ppt	0 (1)	0 (5)
AN31	1 ppt	100 (1)	76 (5)
	10 ppt	0 (1)	12 (5)
MIB	10 ppt	100 (1)	100 (4)
P1	10 ppt	0 (1)	9 (1)
P2	1 ppt	100 (1)	69 (1)
	10 ppt	0 (1)	0 (1)
P3	10 ppt	0 (1)	66 (1)
P4	1 ppt	95 (1)	7 (1)
	10 ppt	0 (1)	1 (1)
P5	10 ppt	0 (1)	10 (2)
NBS Reference Fluid	100 ppm	100 (1)	54 (5)
	1 ppt	21 (1)	0 (5)
	10 ppt	0 (1)	0 (5)

---

[1] From Crawford (1983).

[2] At all lower concentrations, fertilization was not affected.

[3] Figures are all normalized to percentage of control fertilization. Number in parentheses is number of experiments.

TABLE 10. Effects of drilling fluids on echinoderm embryo development[1]

Drilling Fluid	Concentration[2]	*E. parma*	*S. purpuratus*
SV76	10 ppm	No Effect	Prism
	100 ppm	No Effect	Prism
	1 ppt	Early pluteus	Prism
	10 ppt	Gastrula	Blastula
AN31	100 ppm	No Effect	Prism
	1 ppt	Mid pluteus	Prism
	10 ppt	Gastrula	Prism
MIB	1 ppt	Late pluteus	Prism
	10 ppt	Gastrula	Gastrula
P1	100 ppm	Early pluteus	NT[3]
	1 ppt	Early gastrula	
	10 ppt	Morula	
P2	1 ppt	Early pluteus	NT
	10 ppt	Early gastrula	
P3	100 ppm	Mid pluteus	NT
	1 ppt	Early pluteus	
	10 ppt	Late gastrula	
P4	1 ppt	Early pluteus	NT
	10 ppt	Late gastrula	
P5	1 ppt	Mid pluteus	NT
	10 ppt	Early gastrula	
NBS Reference	10 ppm	No Effect	Prism
	100 ppm	Mid pluteus	Prism
	1 ppt	Early pluteus	Prism
	10 ppt	Blastula	Gastrula

---

[1] From Crawford (1983).

[2] Development was not affected at lower concentrations.

[3] Not tested.

TABLE 11. Highest drilling fluid concentrations having no measurable effect on either fish or echinoderm embryogenesis[1]

	"Safe" concentration in most sensitive test	
Drilling Fluid	Concentration (ppm)[2]	Dilution[3]
MIB	100	3,670
SV76	1	1,132,000
AN31	10	65,000
P1	10	106,400
P2	100	11,010
P3	10	133,100
P4	100	11,390
P5	100	13,000
NBS Reference	1	426,000

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[1] From Crawford (1983).

[2] Refer to description of preparation of drilling fluid solutions in test. "Safe" concentration is a concentration 10% of that having an adverse effect on the most sensitive test system.

[3] Dilution of original drilling fluid suspension to achieve the "safe" concentration.

7. Summary of toxicity data

The toxicity of the 11 used drilling fluids tested in this program was generally greater (lower EC50's or LC50's) than previously reported, with the exception of used drilling fluids from Mobile Bay, Alabama. The hydrocarbon content of the drilling fluids was significantly correlated with the toxicity of the fluids -- the higher the content, the greater the toxicity -- except for corals. Sporadic correlation between the metals contents of some muds and toxicity was found, but hydrocarbons were the only constituents that related to toxicity for four of the organisms tested. Variabilities in the preparation of the fluids for chemical analysis and the methods by which the organisms were exposed preclude direct comparison of toxicities among the various organisms. Results of mysid, grass shrimp, and coral exposure to whole muds were related and, to a lesser extent, so were the results of tests with liquid phases with clams and echinoderms. In the latter case, test material preparation was somewhat different and different end-points for sublethal effects were used. Thus, it is instructive to make comparisons of the summary data (Table 12), but comparisons must be made with care. Sublethal effects reported for clams, echinoderms, and corals give a different perspective of toxicity of the fluids but should be related to well-being of the animal at some point, (e.g., the relation of loss of protein and loss of zooanthellae in corals).

The chemical variability of drilling fluids was demonstrated in the concentrations of certain metals and hydrocarbons. However, certain consistencies were exhibited. For example, Al, Ba, Ca, and Fe occurred in parts per hundred concentrations in all of the fluids, but the concentration of these metals differed dramatically within this range in individual fluids. Also, the rank order of concentrations of metals in the whole mud, dissolved, and suspended particulate phases of the different fluids was generally the same.

TABLE 12. Summary of used drilling fluids toxicity data (μℓ/ℓ-ppm)

Mud	Phase	Mysidopsis (LC50)	Palaemonetes (LC50)	Mercenaria (EC50)	Echinoderm Embryo[1]
MIB	WM[2]	>1,500	28,750(26,332-31,274)	>3,000	3,670
	LP[3]	NT[4]			
	SPP[5]	NT		>3000	
	SP[6]	NT			
AN31	WM	1,008(541-1,557)	2,390(1,896-2,862)	2,450	1,132,000
	LP	>150,000			
	SPP	>15,000		1710	
	SP	NT			
SV76	WM	733(429-888)	1,706(1,519-1,922)	87	65,000
	LP	>150,000			
	SPP	17,633(15,123-19,835)		117	
	SP	>50,000			
P1	WM	26(14-39)	142(133-153)	719	106,400
	LP	>150,000			
	SPP	1,936(1,641-2,284)		122	
	SP	1,456(1,246-2,437)			
P2	WM	459(301-732)	4,276(2,916-6,085)	319	11,010
	LP	116,419(111,572-121,476)			
	SPP	18,830(14,068-22,522)		158	
	SP	NT			
P3	WM	92(87-98)	658(588-742)	682	133,100
	LP	>30,000			
	SPP	726(650-791)		64	
	SP	9,808(8,066-19,558)			
P4	WM	>1500	4,509(4,032-5,022)	330	11,340
	LP	97,238			
	SPP	27,233(24,791-29,265)		338	
	SP	NT			

(continued)

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[1] Dilution of original drilling fluid required to reach "safe" concentration.
[2] Whole mud.
[3] Liquid phase.
[4] Not tested.
[5] Suspended particulate phase.
[6] Solid phase.

TABLE 12. Continued

Mud	Phase	Mysidopsis (LC50)	Palaemonetes (LC50)	Mercenaria (EC50)	Echinoderm Embryo
P5	WM	263(115-379)	3,570(3,272-3,854)	380	13,00
	LP	>150,000			
	SPP	24,770(11,380-38,362)		82	
	SP	>50,000			
P6	WM	>1,500	100,000	>3,000	NT
	LP	>150,000			
	SPP	>50,000		>3,000	
	SP	>50,000			
P7	WM	728(470-1958)	35,420(32,564-38,877)	>3,000	NT
	LP	>150,000			
	SPP	>50,000		2,889	
	SP	NT			
P8	WM	>1500	2,557(2,231-2,794)	269	NT
	LP	>150,000			
	SPP	27,137(26,025-28,070)		220	
	SP	NT			

C. TOXICITY OF LABORATORY-PREPARED GENERIC DRILLING FLUIDS

Acute toxicity tests were conducted during August-September 1983 with eight laboratory-prepared, unused generic drilling fluids and mysids at ERL/GB and ERL, Narragansett, Rhode Island (Duke et al., 1984). These tests were conducted at the request of the EPA Office of Water Regulations and Standards to determine the acute effects of eight fluids whose composition was known and the effects of two of the drilling fluids which had been purposely contaminated with mineral oil.

The generic drilling fluid concept was developed jointly by EPA's Region II and industry to provide EPA information on the impact of drilling fluids and components of the fluids released into the environment without requiring each drilling operator to perform repetitious toxicity tests and chemical analyses. The eight generic drilling fluids include virtually all water-based fluids used on the OCS. Only major components of the generic fluids are specified and additional information concerning the effects of speciality additives must be submitted to EPA prior to their discharge. The generic fluid concept is now being employed by various EPA Regional Offices involved in the permitting process (Petrazzulo, 1983).

Test methods followed those proposed by Petrazzuolo (1983), with the following exceptions: (1) tests were conducted with natural, not artifical, seawater; (2) 5±1-day-old mysids were used in the tests rather than 4±1-day-old mysids; (3) test mixtures were aerated during the 96-h exposures; and (4) for the mineral oil tests, glassware was rinsed with petroleum ether to ensure removal of the oil and then washed as prescribed.

The test material was the suspended particulate phase (SPP) of each drilling fluid. The SPP was prepared by mixing volumetrically 1 part drilling fluid:9 parts seawater and allowing the resulting slurry to settle for one hour.

The material that remained in suspension was the SPP.

A positive control in which mysids were exposed to the reference toxicant, sodium lauryl sulfate, was maintained with each drilling fluid test. Results of the tests were in accordance with toxicity values reported in the literature for this reference toxicant, demonstrating that the mysids were in acceptable condition for testing.

To confirm the validity of the tests conducted with the generic fluids at ERL/GB, two drilling fluids were tested at Narragansett. Results of the tests, expressed as percentage SPP, are given in Table 13.

The addition of mineral oil to generic drilling fluids #2 and #8 dramatically increased their acute toxicity to mysids. When 1% mineral oil was added, the 96-h LC50 changed from 51.6% to 13.4% for fluid #2 and from 29.3% to 7.1% for fluid #8. Addition of 5% and 10% mineral oil further increased toxicity, as can be seen in Table 14.

There was a significant negative correlation between mineral oil content and the 96-h LC50 for each fluid; Spearman's $r = -0.98$ with a probability ≤ 0.0001.

The response of the mysids to the reference toxicant was within an acceptable range, demonstrating that the test animals were in suitable condition.

A detailed description of the source and composition of the generic drilling fluids and mineral oil is contained in Appendix D.

TABLE 13. Results of acute toxicity tests with eight laboratory-prepared generic drilling fluids and mysids (*Mysidopsis bahia*)

Test Location	Drilling Fluid	Definitive Test[1] (96-h LC50 & 95% CL)	Positive Control[1] (96-h LC50 & 95% CL)	Definitive Test[2] (96-h LC50 & 95% CL)
Gulf Breeze	#1	2.7% SPP[3] (2.5-2.9)	5.8 ppm[4] (4.3-7.6)	3.3% SPP (3.0-3.5)
	#2	51.6% SPP (47.2-56.5)	7.5 ppm (6.9-8.1)	62.1% SPP (58.3-65.4)
	#3	16.3% SPP (12.4-20.2)	7.3 ppm (6.6-8.1)	20.3% SPP (15.8-24.3)
	#4	12% mortality in 100% SPP	3.4 ppm (2.8-4.1)	---
	#5	12% mortality in 100% SPP	Same as for #1	---
	#6	20% mortality in 100% SPP	6.0 ppm (5.4-6.6)	---
	#7	65.4% SPP (54.4-80.4)	Same as for #6	68.2% SPP (55.0-87.4)
	#8	29.3% SPP (27.2-31.5)	Same as for #3	30.0% SPP (27.7-32.3)
Narragansett	#1	2.8% (2.5-3.0)	6.2 ppm (4.4-11)	---
	#5	No mortality in 100% SPP	3.3 ppm (2.6-3.8)	---

[1] Calculations by moving average; no correction for control mortality unless stated.

[2] Calculations by SAS® probit; correction for all control mortality. Analyses performed R. Clifton Bailey, U.S. EPA, Program Integration and Evaluation Staff (WH-586), Office of Water Regulations and Standards, Washington, DC 20460.

[3] The suspended particulate phase (SPP) was prepared by mixing 1 part drilling fluid with 9 parts seawater. Therefore, these values should be multiplied by 0.1 in order to relate the 1:9 dilution tested to the SPP the whole drilling fluid.

[4] Corrected for 13% control mortality.

TABLE 14. Results of acute toxicity tests with two laboratory-prepared generic drilling fluids without and with mineral oil added and mysids (*Mysidopsis bahia*)

Drilling Fluid[1]	96-h SPP[2] LC50	95% Confidence Limits
#2	51.6%	47.2-56.5%
#2-01	13.4%	11.1-16.9%
#2-05	1.8%	1.4-2.2%
#2-10	0.49%	0.39-0.62%
#8	29.3%	27.2-31.5%
#8-01	7.1%	5.7-9.0%
#8-05	0.90%	0.74-1.1%
#8-10	0.76%	0.63-0.87%

[1] The two digits following the generic drilling fluid number indicate the percentage of mineral oil in the fluid.

[2] The suspended particulate phase (SPP) was prepared by mixing 1 part drilling fluid with 9 parts seawater. Therefore, these values should be multiplied by 0.1 in order to relate the 1:9 dilution tested to the SPP of the whole drilling fluid.

D. ENVIRONMENTAL CONCENTRATIONS

As reported in the NRC (1983) report, the initial plume of drilling fluid, immediately after discharge on the OCS, is denser than seawater. The plume "goes through a stage of convective descent until it encounters the seabed or becomes neutrally buoyant from loss of solids and water entrainment." Because of the density gradient of the plume, it then "collapses and goes into a stage of passive diffusion." There is also an upper, visible plume in addition to the main or lower plume. The upper plume is caused by the turbulent mixing of the main plume with seawater. It contains only a small fraction (<10%) of the discharged drilling fluid and cuttings.

NRC (1983) also reported that most of the discharged material (barite, flocculated clays, and formation solids) sinks to the bottom within 500 m of the discharge point for most OCS areas. Of course, the water depth, lateral transport (current, tides, etc.), particle size, and density of the drilling fluid and cuttings influence the fate of the material. For the drilling fluid and cuttings solids that reach the bottom, the most important factor governing their redistribution and ultimate fate is the shear velocity. Sediment type, bioturbation, bottom configuration, and characteristics of suspended sediment near the bottom all influence shear velocity. Thus, it is difficult to establish a "normal" benthic concentration. Field studies have shown that prevailing conditions at the discharge site cause wide variation in fate of materials on the bottom. For the water column, however, the situation is better defined. Components of drilling fluids investigated in field studies (barium, chromium, and iron, for example) usually undergo a rapid dilution immediately after discharge so that a concentration of 30 to 50 ppm of drilling fluid solids is reached within a few minutes. Within 1 h, the dilution factor is 10^6 or greater and concentrations within 100 to 200 m of the discharge point are 1 ppm or less.

Proni (1984) studied the fate of drilling fluids and cuttings discharged from active drilling rigs in the northwestern Gulf of Mexico near the Flower Garden Banks and came to the following conclusions:

(1) Because of the physical nature of drilling fluids (>50% of the particles are <2 μm and no significant percentage is >62 μm), the "water column density structure will play an important part in drilling fluid dispersion."

(2) Because an increase in total suspended material was observed at or above the pycnocline for one discharge, "water column isopycnal surfaces and relatively large density gradients can act as an essentially continuous, horizontal conduit for drilling fluids."

(3) Based on acoustical data from 10 min of one transect, "the possibility of continuous surfaces within the water column for the transport of drilling fluids exists."

(4) Consideration of drilling fluid concentration, the point of discharge, and the time of discharge must be based on site-specific, discharge-specific factors.

(5) In the Flower Garden Banks, the distance from the point of discharge to the corals will partially determine whether or not drilling fluids reach the corals. The most important range is the medium range, 0 to 10 kilometers [6.2 miles]. "This range is important because turbidity flows here can reside at the proper depth to reach the corals (shallower than 60 m or so)...."

(6) "It appears possible that mid-water components of drilling have a possibility of reaching the corals of the Flower Garden Banks; however, it appears unlikely that drilling fluid material once within the oceanic boundary layer can be brought by resuspension mechanisms to the depth of the corals and

then transported to the corals."

(7) There is a 10^6 dilution in the immediate vicinity of the rig when drilling fluids are discharged, based on field data. A further dilution of 10^6 to 10^7 is probable in the medium range (0 to 10 km), based on model calculations and other types of discharges. [Thus a one-trillion or greater dilution will likely result within a 6.2-mile radius of a drilling rig.]

(8) More work is needed to better understand the dispersion of drilling fluid discharges.

E. ADAPTIVE ENVIRONMENTAL ASSESSMENTS

Scientists, administrators, and regulators utilized the AEA approach to synthesize available data on the impact of drilling fluids on the marine environment and to develop a hazard assessment. Two AEA workshops were held to make this assessment, the first in 1981 and the second in 1983. The results of the second workshop are preliminary, but offer some useful concepts concerning discharge and impact on benthic communities.

Scientists at the International Institute for Applied Systems Analysis in Austria and the University of British Columbia in Vancouver developed the AEA method. This methodology can be applied at the beginning of a research project to formulate a research plan or to synthesize data produced in an on-going project, as well as to point out weaknesses or gaps in the data. The synthesizing aspect was applied to drilling fluids when representatives from industry, academia, and government met for a 5-day workshop in November, 1981, and for 3 days in June, 1983.

The focus of both workshops was the construction and refinement of a quantitative, dynamic simulation model to describe the impact of drilling fluids on the environment. The methodology of AEA is such that the process of building the model can be more important than the model itself. Development of the models permitted participants to focus on the issues and data at hand, even though their approach to the problem may have differed. The process also required participants to take a more holistic approach to the question of impact. Those developing toxicity data communicated directly with those estimating environmental concentrations. Participants in these workshops agreed at the onset that the models produced by this effort would serve as a tool for evaluating the impact of drilling fluids on the environment, and that it would not be appropriate to make environmental evaluations on the basis of the models alone.

The following are excerpts from the workshop proceedings.

First AEA Workshop

In the first workshop (Auble et al., 1982), a hypothetical drilling operation in open waters of the Gulf of Mexico was chosen for the model structure. The drilling fluid discharge plume in the water column was represented by a set of plume-slice intervals, each representing 1 min of discharge. On the bottom, environmental effects in 1-m^2 areas at five distances downstream were established. A time horizon of 20-30 years (yrs) was selected for this model. Incremental time steps varied from 1 min in the water column to one month elsewhere.

The following major components or submodels were designated by workshop participants:

(a) Discharge/fate -- characteristics of discharge plume and fate of materials in the plume:

(b) Water-column effects -- impact of discharge on zooplankton in upper plume:

(c) Soft-bottom effects -- effects of discharge on microbes, meiofauna, and macrofauna; and

(d) Hard-bottom effects -- response of coral to exposure to drilling fluids.

An additional subgroup considered at the same time the impact of drilling fluids on enclosed or semi-enclosed bodies of water, such as bays and estuaries. This group did not construct a model, but focused on variables that would differ between open and closed systems.

After the submodels were developed, linkages among the submodels were defined. This required each subgroup to develop specific submodels.

a. Discharge/Fate Submodel

Dispersion ratios, the ratio of suspended solids in the discharge to suspended solids in the upper plume, were calculated from a multiple regression, using transport time and the inverse of discharge rates as independent variables:

$$DISPR = 10^{4.4495} * (1/DSCHR)^{0.35674} * (TT)^{1.1001}$$

where DISPR = Dispersion Ratio,

DSCHR = Discharge Rate (bbl/h), and

TT = Transport Time (min).

This regression was based on observed dispersion ratios from three wells, summarized by Petrazzuolo (1981). The squared correlation coefficient (R^2) for this regression was 0.74.

Plume volume, dilution factor for the upper plume, and dispersion ratios for solid fractions were calculated by the model, assuming a 10 m/min current and total discharge of 600 bbl. Sediment build-up on the bottom was also calculated and adjusted for storm surges.

Although the discharge/fate submodel provided reasonable plume characteristics for use of the other submodels, it lacked explicit mathematical treatment of detailed physical and chemical plume characteristics and some environmental variability.

b. Water Column Effects Submodel

This model used an estimate of the proportion of water column planktonic organisms within the plume that could be killed by single discharge as an indication of the health of the water column organisms. Zooplankton mortality in the plume was used to estimate percentage loss in monthly recruitment of larval forms to the benthos.

The shape and characteristics of the plume supplied by the discharge/fate submodel were divided into slices, each representing 1 min of discharge. The concentration of an organism's exposure in a given plume would decrease with time because it was assumed that animals entrained at any point would be carried by currents that moved the plume and thus be exposed to a decreasing concentration gradient.

The model was used to compute average concentration (C_{st}) for the period of exposure (t) of each subpopulation

$$c_{st} = \frac{\sum_{i=s}^{s+(d-t)} c(i)}{(d-t+1)}$$

where c_{st} = mean exposure concentration for organisms entering slice "s" at time "t" (where t=1 is first min of discharge),

c(i) = concentration of solubles (ppm) in slice "i", and

d = total duration of discharge (min).

Following Petrazzuolo (1981), an LC50 value appropriate to each subpopulation's "t" min of exposure was estimated thusly:

$$\text{t-min LC50} = \text{96-h LC50} \times \left(\frac{96\ \text{h}}{t\ \text{min}} \times \frac{60\ \text{min}}{\text{h}}\right)^{1/2}$$

Total plume mortality and potential monthly benthic recruitment losses were calculated from a 50 ppm LC50 and concentration of drilling fluid at time t where t was considered to be 120 min. Calculations indicate that even with 100% mortality in the plume, monthly reduction in potential benthic recruitments would be small.

The major limitation to this model is the extrapolation of 96-h LC50 toxicity data obtained in the laboratory at constant concentration to toxicity or organisms exposed to decreasing concentrations in the field for shorter periods of time. In the model, LC50 for shorter time-periods would be increased by a factor equal to the square root of the relative exposure time. This may not be appropriate, however, for organisms with short generation times.

c. Soft-Bottom Effects Submodel

Construction of this submodel required considerable simplification of complex biological processes and can be considered a rather general conceptual model. A basic assumption was that soft-bottom areas in the Gulf of Mexico were subjected to frequent storm events. Thus, the community was chiefly composed of "invader" species characterized by rapid recovery and colonization. The submodel dealt with the bioaccumulation, survival, and sublethal response of four indicator groups.

Bioaccumulation of chromium from bottom sediments was related to the fraction of whole drilling mud resulting from discharge. Oyster flushing rates were used to account for the benthos' ability to flush excess chromium from their tissue. Predictions of chromium content of epifaunal tissues indicated that 0.04 fraction of whole drilling mud in the sediment would yield tissue concentrations of about 8 ppm, and 0.08 fraction, about 35 ppm.

Mortality was caused by burial of discharged mud, toxicity of the mud, and by removal of deposited sediments by storms. Population changes due to storm intensity were indexed according to the amount of sediment removed by each storm. The model indicated that 0.04 fraction of whole mud in sediment will result in about a 0.60 survival rate and 0.08 will cause about a 0.20 survival rate. Monthly survival rate will be reduced to 0.50 by a 150-cm deep overlay. Population recovery, as colonization, was affected by such factors as depth of deposited sediment, fraction of whole mud, and re-establishment of an oxygenated layer. A plot of the fraction of first-month potential recolonization due to toxicity of residual muds (indicated by fraction of whole mud in the sediment) showed that 0.010 fraction whole mud would permit about 78% of the community to recolonize.

Limits of this model include overemphasizing the "invader" species concept and their resistance to burial. Also, the lack of consideration of interdependence among faunal groups and the need to use short-term toxicity data to predict long-term effects may cause over- or underestimates of effects.

d. Hard-bottom Effects Model

The hard-bottom model uses the impact of drilling fluids on corals as indicator organisms because of the lack of data on other organisms, such as sponges and gorgonians. Coral were considered as individuals, rather than the entire reef community. Uncertainty in four major impacts of fluids on corals, mortality due to sediment deposition, direct mortality due to plume toxicity, reduced growth due to plume toxicity, and reduced recruitments due to burial of appropriate substrates were resolved in favor of a "worst-case" basis. Biomass dynamics of the coral were represented by the following equation:

$$C_{t+1} = C_t - SC_t - PC_t + G + R$$

where C = coral biomass,

S = mortality due to burial,

P = mortality due to toxic plume,

G = growth, and

R = recruitment.

Survival rates were calculated as a function of depth and indicated 0.50 survival rate at 2 cm depth of sediment coverage and 0.25 rate at about 2.5 cm depth. Monthly survival rate of 0.50 occurred at about 900 ppm suspended solids and 0.25 survival at about 1,200 ppm. The growth rate of corals was reduced approximately 85% when they were exposed to 100 ppm suspended material.

Limitations of the model include the lack of factors relating the interaction of corals with the coral community and extrapolation of 96-h LC50 data to shorter time intervals. Corals were the only organisms tested that represented hard-bottom communities; many other organisms occupy this niche of the marine ecosystem and should be tested.

The four submodels were utilized in a system model to produce holistic output in the following manner: for each monthly iteration, the discharge/fate submodel calculated upper plume characteristics and deposition of drilling muds and cuttings; the water column submodel next calculated impacts of the upper plume on zooplankton and benthic recruitment, and the soft- and hard-bottom submodels then calculated potential impact.

The sample outputs shown in Table 15 are presented as approximate maxiumum values. Participants in the workshop considered these values useful in addressing semi-quantitative changes and trends, but did not consider them to be absolute numbers. The values represent only a point from which discussions can take place and the limits of applicability of the models to actual field conditions can be determined.

e. Bays and Estuaries

Much of the data and discussions developed for offshore areas are applicable to enclosed bodies of water, such as bays and estuaries. However, some characteristics of enclosed areas preclude a simple extrapolation. Participants of the workshop suggested that the following modifications of their models representing open waters would be needed in order to adapt them to estuarine areas:

(1) Additional communities, such as aquatic macrophytes and oyster beds, would have to be treated.

(2) The importance of enclosed water bodies as food production and rearing areas would necessitate more detailed incorporation of population level

Table 15. System model scenarios[1]

		VARIABLE					SAMPLE OUTPUTS (APPROXIMATE MAXIMUM VALUES)								
SCENARIO	PLATFORM TYPE	Water Depth (m)	Dsch. Rate	Total Dsch. (million tons)	Time (yrs)	Maximum Depth of Spent Mud Deposit	Fraction Whole Mud In Sediment			Conc Suspended Sediments In Upper Plume (ppm)			Coral Biomass		
							50m	100m	500m	50m	100m	500m	50m	100m	500m
I	Production	80	600 bbl every 3 days; 1,000 bbl/h max.	1,500	20[2]	15 cm in 154-m circular area	0.12	0.09 (3 yrs)	0.02	58	28 (3 yrs)	5	0	0 (5 yrs)	90
II	Production	80	600 bbl every 3 days; 30 bbl/h max.	1,500	20	15 cm in 154-m circular area	0.12	0.09	0.02	20	9	1.5	0	0	90
III	Production	20	600 bbl every 3 days; 100 bbl/h max.	1,500	20	34 cm in 33-m circular area	0.16	0.12	0.02	58	28	5	90	60	50
IV	Production	20	600 bbl every 3 days; 30 bbl/h max.	1,500	20	34 cm in 33-m circular area	0.16	0.12	0.02	20	9	1.5	0	0	50

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[1] From Auble et al. (1982).

[2] Drilling begins in 1st year and ends in 3rd year.

processes and trophic interactions.

(3) Many of the processes represented in the open water simulation model, such as plume dynamics, sediment deposition, and sediment redistribution, would require fundamentally different mathematical treatment due to shallower water and more complex circulation and stratification patterns.

(4) The importance of resuspension in shallower water and slower, long-term dispersion would necessitate more detailed consideration of long-term effects of slightly elevated drilling fluid concentrations.

Second AEA Workshop

The results of this workshop, held in June, 1983, are in preliminary form at the time this report is being written[1]. The proceedings of the workshop are still undergoing review by participants, but the preliminary data reveal some interesting concepts.

The focus of the second workshop was on refinement and extension of the previous models in the areas of fate and effects on soft-bottom benthic communities. Objectives included development of a model for potential impacts that adequately quantifies selected indicators as measures of impact and qualifies these estimates in terms of their levels of error or uncertainty. Also, algorithms were produced that are compatible with microprocessor capabilities. The model described in the preliminary report was implemented on a main-frame computer and the possibility of implementation on microprocessors has yet to be evaluated.

Considerable refinements of the first models were included in the second model, but it still represents a compromise between useful detail and over-simplification. The model does not attempt to duplicate the detail of plume dynamics represented in models such as the one being developed by the Offshore Operators Committee[2]. Rather, the second AEA model attempts to connect representations of the fate processes with those of the effects processes to produce a model that can be examined from a holistic ecosystem point of view.

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[1] Personal communication. Gregory T. Auble. U.S. Fish and Wildlife Service, Western Energy and Land Use Team, 2625 Redwing Road, Fort Collins, Colorado 80525.

The model simulates the depth of material deposited from each discharge event at seven distances from the discharge point. Discharges are categorized according to particle size (three classes), concentrations of hydrocarbons and chromium, ratios of solids dispersion and soluble dilution in the surface plume, and whether the fluids are distributed along the track chosen for determining biological effects is also given. The model can be reparameterized to represent different geographical regions by varying water depth, current velocity, etc., and different drilling fluids by varying density and chromium and hydrocarbon content.

Sediment dynamics are calculated by accounting for the movements of various types of sediment at each 1-m^2 plot along the transect. The sediment profile at each plot is partitioned into (1) top layer with a fixed thickness of 5 cm, (2) bottom layer of variable thickness, and (3) underlying natural sediment. Each layer is considered to be completely mixed. Resuspension events are considered to disturb a certain thickness of sediment where disturbed sediment is moved off and replaced by an equivalent thickness of natural sediment. Therefore, an event would alter sediment composition, but not thickness.

The workshop model considers that the benthic community contains three assemblages: (1) a meiofaunal assemblage; (2) a pioneer or early successional macrofaunal assemblage; and (3) a late successional macrofaunal assemblage. The overall model predicts specific conditions that will exist after discharge and sediment redistribution, and the community section of the model calculates the number of individuals per m^2 under the specific conditions. Four processes may change the species assemblages in the model: (1) mortality due to burial by deposited mud and cuttings or natural sediments; (2) mortality due to toxicity of deposited mud and cuttings; (3) mortality due to resuspension events, such as storms and ice movement; and (4) population growth due to both asexual reproduction and larval recruitment.

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[2] Personal communication. R.C. (Bob) Ayers, Jr. Chairman, Offshore Operators Committee on Environmental Science, P.O. Box 50751, New Orleans, Louisiana 70150.

The mortality rate for burial is calculated as a function of depth of deposited sediment as a result of "indigenous" sediments and exotic sediments which differ in particle size distinctive from natural sediment. The model must rely on existing data on a few species, so *Mysidopsis* sp. (mysids) represent early macrofaunal assemblages and *Palaemonetes* sp. (grass shrimp) represent late successional macrofaunal assemblage. It should be noted that the toxicity data can be changed to represent more or less sensitive species when appropriate data are available. Intensity of resuspension effect is measured by the thickness of sediment disturbed and mortality rates for each species assemblage was estimated by the workshop participants. Growth was represented by logistic equations with some modifications to represent competitive effect of individuals of the late successional macrofaunal assemblage.

Several scenarios were developed and parameterized at the workshop, but at this time, output from the scenarios should not be extrapolated to conditions at specific sites. Rather, they may be considered as model performance that represents a range of regional conditions in which discharge may occur. Outputs are presented as tables, 1-yr graphs of daily values, and multiyear graphs of monthly data. Several parameters for the four scenarios are presented in Table 16.

Scenario 1 represents a cold-water, high-latitude environment that might

TABLE 16. Water column and drilling fluid characteristics, 2nd AEA Workshop[1]

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Water Column Characteristics				
water depth (m) (WDEPTH)	5	20	80	1,000
surface current (cm/sec) (SCURR)	13	25	15	10
bottom current (cm/sec) (BCURR)	13	10	5	1
proportion of time current in direction of sample transect (from current rosette) (CFREQ)	0.40	0.40	0.70	0.40
ambient density in surface layer (g/cm^3) (PO)	1.025	1.025	1.025	1.025
density gradient ($g/cm^3/m$) (PA)	1.0E-4	4.0E-4	4.0E-4	2-0E-4
Drilling Fluid Characteristics				
density (lb/gal) (DENSM)	13	13	13	13
% liquid (PWAT)	79.5	79.5	79.5	79.5
[Cr] (mg/l) (CRCONC)	400	400	400	400
[#2 fuel oil] (mg/l) (HYCONC)	9.43	9.43	9.43	9.43

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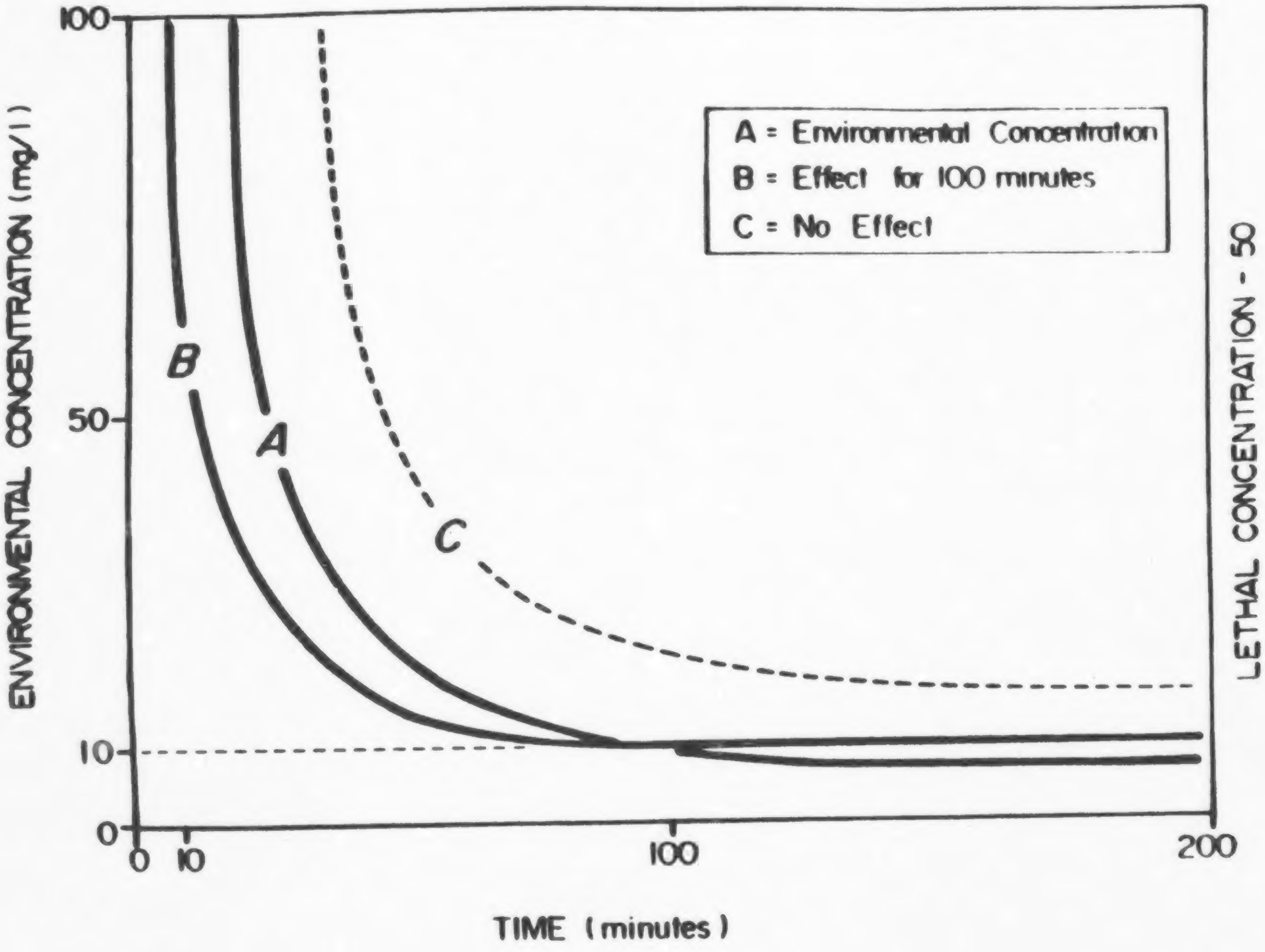
[1] Personal communication. Gregory T. Auble. U.S. Fish and Wildlife Service, Western Energy and Land Use Team, 2625 Redwing Road, Fort Collins, Colorado 80526.

be encountered in the Beaufort Sea. The water depth is 5 m and ice scour (causing leveling of sediments) occurs infrequently. Scenario 2 represents shallow water conditions that might be encountered in the Gulf of Mexico. The water depth is 20 m and hurricanes occur only infrequently. The mud plume is considered to impact the bottom. Scenario 3 represents a deeper well in the Gulf of Mexico. The water depth is 80 m and the current is more undirectional than in Scenario 2. Scenario 4 represents discharge in very deep water (1,000 m) and contains no sediment resuspension events. The results from each scenario are, of course, dependent upon the parameters set forth for each by the workshop participants. The parameters and basis for their selection will be presented in detail in the workshop proceedings.

Each of the AEA workshops produced models that, under a given set of parameters, can predict the fate of the discharge plume and selected effects on water column and benthic organisms. As stated previously, the values obtained by these models (thickness of mud at various differences and reductions in numbers of animals) only "bound" the question because of the many assumptions that must be made in order to model the system and because of the lack of data applicable to the model. Each of these models and others developed to predict the impact of drilling fluids on the environment can contribute data for a hazard assessment. That is, they can predict the environmental concentration of drilling fluids on a temporal and spatial basis and also predict biological effects from those concentrations. A conceptual illustration of how the model outputs can be used in a hazard assessment is shown in Figure 3. The ultimate goal is to predict when the curve representing an effect (for example, an effect on a bottom community) intersects or approaches the curve representing environmental concentration. It is a matter of judgment concerning how closely the effect curve should be allowed to approach the concentration curve. Also, as more effects measurements with appropriate organisms and physical and chemical measurements relating to concentration are obtained, the more confidence can be placed in the curves and thus the hazard assessment.

FIGURE 3. Use of Adaptive Environmental Assessment (AEA) model outputs in hazard assessment.[1]



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[1] From Duke (In press).

RECENT REVIEWS AND REPORTS

The scientific literature concerning fates and effects of drilling fluids (both used and fabricated especially for testing) and of individual components of drilling fluids has been subject to intensive review. In addition to a review funded by this project (Neff, 1982), the report by NRC (1983) provides an assessment of the fates and effects of drilling fluids and cuttings in the marine environment. The reader is urged to use the abundant information and references available in this single publication to understand better the uses, discharge characteristics, toxicity and bioavailability, and special considerations for drilling fluids. Also, three recent reports by the National Oceanic and Atmospheric Administration/National Marine Fisheries Service (NOAA/NMFS) provide additional information. The following excerpts from these reviews and reports are presented to aquaint the reader with background information in drilling fluids. The findings do not necessarily agree with findings from the ERL/GB program.

NRC report

NRC (1983) stated that drilling fluids have been, are, and will be essential to the exploration and production of gas and oil, and they must be disposed of, either on land sites or in the ocean. The quantity of drilling fluids and cuttings discharged annually in the OCS is approximately two million metric tons (dry weight), of which about 90% is discharged in the Gulf of Mexico.

Acute toxicity data show that most water-based drilling fluids tested to date are "relatively nontoxic," that is, the acute LC50 (concentration lethal to 50% of the test organisms) for whole fluid is >1,000 parts per million (ppm) and for the suspended particulate phase (SPP) is >10,000 ppm. Most acute toxicity can probably be attributed to the use of diesel fuel

(#2 fuel oil) or other specialty additives in the drilling fluid.

Although some sublethal tests on growth, development, and reproductive success have been conducted, the exposure concentrations and exposure intervals [duration] have not been representative of the conditions characteristic of dispersing plumes of drilling fluids in the field. [This criticism also applies to acute test design and conduct]. Similarly, tests with benthic organisms have not simulated the dispersion of discharged drilling fluids which has been measured in the field. Thus, the results of benthic microcosm studies are "difficult to interpret."

The test species appear to be appropriate. Organisms from one region have not been more or less sensitive than organisms from another region, and nearshore organisms have been equally sensitive to drilling fluids as those morphologically-similar species from offshore. Thus, nearshore species appear to be appropriate surrogates for toxicity testing.

Recognizing that discharges of drilling fluids and cuttings take place under a wide range of environmental conditions, there are still valid generalizations which can be made about the fate of the fluids and cuttings. Approximately 90% of drilling fluid particles (and almost all the cuttings) rapidly settle until they encounter the seabed or become neutrally buoyant. In addition to this main (lower) plume, an upper, visible plume is formed which may be diluted horizontally by a factor of 10,000 or more within 1 h after release. Thus, the anticipated exposure of water-column organisms to the suspended particulate phase of a discharged drilling fluid would be of approximately 1-h duration and 100 ppm concentration. This exposure would likely occur only within an area tens of meters from the discharge point. [Further dilution occurs farther from the platform]. Considering benthic organisms, most discharged drilling fluids and cuttings are deposited on the OCS within

1,000 m of the discharge point. The amount of current and tidal action [energy] at the site would determine the rate of dispersion and/or resuspension. Adverse effects to the benthos may be caused by physical (burial) or chemical (toxicity) factors.

There are at least four major deficiencies in the information base for assessing the fates and effects of drilling fluids and cuttings discharges on the OCS: "variable quality of research, limits to the realism and relevance of laboratory experiments, difficulties in unequivocally ascribing effects observed in field studies to given causes, and a poor understanding of ecosystem processes." Any further drilling fluids research should include acute, sublethal, and chronic studies in which techniques and exposures reflect actual discharge and exposure conditions.

Finally, drilling fluids and cuttings discharges should be such that "particularly sensitive benthic environments, especially hard substrate epibiota, which are not exposed to significant natural sediment flux" will not be buried, and the use of toxic additives, such as diesel, should be monitored or limited.

Neff review

Neff (1982) characterized the majority of major drilling fluid ingredients as being "biologically inert" or having "a very low order of acute toxicity." In all but a few cases where 70 used offshore-type drilling fluids had been tested with more than 60 species of marine animals, the LC50's (usually 96-h) were 10,000 ppm or higher. An adverse effect on water column organisms is likely to occur only to the most sensitive species or life stage in the immediate vicinity of the drilling fluid discharge (< 1,000 m) and only for a brief time (less than 2 h), according to Neff. Benthic fauna, however, may be damaged by settling drilling fluid and solids, through either burial or chemical toxicity. Heavy metals associated with fluids or cuttings would be biologically available only on a very limited basis. Neff concluded that the discharge of used water-based drilling fluids in marine waters poses "no as yet measurable hazard of more than very localized and transitory impact on the marine environment."

NOAA/NMFS administrative report to EPA

Three reports dealing with ecological effects of energy development on the Flower Garden Banks in the Northwestern Gulf of Mexico have very recently been published by NOAA/NMFS (Kennedy et al., 1983; Grizzle, 1983; and Boland et al., 1983). Kennedy and coworkers investigated the effects of discharges from two drilling platforms on standing stocks, local distribution, and community structure of the macroinfauna living around the East and West Flower Garden Banks. No definitive evidence was found that drilling activities at either platform "produced significant impacts upon sediment texture, total organic carbon (TOC), or the associated macroinfauna." Although there were some changes in polychaete community structure during the 2-year study, the authors attributed the cause to the passage of Tropical Storm Chris through the area. Grizzle examined fishes from the Flower Garden Banks for gross and microscopic lesions. He found that most grossly visible lesions were caused by parasites and that there was no observable difference in types or prevalence between fishes collected near the drilling rigs or from control areas. He did find significantly higher liver weight-to-body weight ratios in certain fishes collected near the drilling platforms and stated that the greater liver weight could have resulted from "differences in food between stations or because toxicants affected the fish near platforms." He also reported that certain fishes collected near the drilling platforms had "more frequent or severe gill lamella epithelium hyperplasia and edema, chronic hepatitis, and hepatocyte basophilia than controls." He suspected toxicants as the cause of the lesions but did not identify a specific toxicant because "the lesions found could have been caused by a wide variety of chemicals." Boland and coworkers studied the reef fish populations in the area and found that the "characteristic fish assemblages" that were present were not measurably affected before or during drilling activities. Indeed, they found enhancement of fish populations: "One of the most significant overall effects of the installation of the Mobil Platform HI-A389-A in proximity to the East Flower Garden Bank was its colonization by a diverse community of epibiota and fishes where none existed before."

CONCLUSIONS

Results of research activities from this and other projects show that drilling fluids are toxic to marine organisms at certain concentrations and exposure regimes. Further, drilling fluids can adversely affect animals -- expecially benthos -- through physical contact, by burying, or by altering substrate composition. Drilling fluids also can exert effects by disrupting essential physiological functions of organisms.

Much less information is available on the environmental concentrations of drilling fluids that result from discharges into the marine environment than is available on toxic effects. However, available data and models suggest that when discharges are made from platforms located in open, well-mixed, and relatively deep (>20 m) marine environments under the ranges of operating and environmental conditions discussed in the Adaptive Environmental Assessment workshops, most detectable acute effects will be limited to within several hundred meters of the point of discharge. Based on laboratory-derived effects data, there will be sufficient dilution of the drilling fluids in the water column (10^6 dilution within approximately 1,000 m of the point of discharge) to minimize acute effects on water column organisms similar to those tested to date. Benthic organisms within about 300 m of the discharge will be potentially subject to adverse effects caused by burial and chemical toxicity; they may also be susceptible to direct effects or substrate changes for greater distances. Possible exceptions to these generalizations could occur when discharges are near sensitive biological areas, such as coral reefs, or in poorly flushed environments.

Laboratory toxicity tests indicated that #2 fuel oil of known composition, "diesel-like" hydrocarbons in used drilling fluids from the Gulf of Mexico, and mineral oil were correlated with toxicity -- the higher the hydrocarbon content, the greater the toxicity. Tests showed that when API #2 fuel oil (diesel) was added to one of the used fluids with a low "diesel" content, the treatment increased the toxicity of the fluid to grass shrimp. Similar results were obtained when mineral oil was added to laboratory-prepared generic drilling fluids; the toxicity of fluid to mysids increased as the concentration of mineral oil increased. Experiments conducted with grass shrimp indicated that when equal amounts of API #2 fuel oil and mineral oil were added to a hydrocarbon-free reference drilling fluid prepared by the National Bureau of Standard for use in the ERL/GB research program, the fuel oil-treated preparation was about three times more toxic than the reference fluid with mineral oil added. Additional tests are needed to compare the toxicity of these two additives to other organisms as well as tests to determine their no-observed-effect concentrations on various species and communities. It would also be useful to establish a data base on the long-term toxicity of other drilling fluid additives, including biocides.

More data on sublethal and chronic effects should be developed to assess the potential long-term toxicity of drilling fluids to benthic communities. Such studies should generate information on the bioaccumulation of specific drilling fluid components. Additional evaluations of the toxicity of Cr^{+3} and Cr^{+6} and the effects and bioavailability of other drilling fluid components such as barite are also needed. Additional research also is needed to quantatively address the limits of applicability of the assumptions and inputs of the fate models developed in the AEA workshops in order to validate the models. Special emphasis should be placed on the evaluation of models of discharges from multiple development rigs because these are the sites of the most intensive drilling fluid discharges.

The Adaptive Environmental Assessment process appears to be a sound approach in developing models to understand the fate and effects of drilling fluids discharged in the marine environment. Development of the AEA models has accentuated certain gaps in our knowledge and has emphasized the importance of considering the potential magnitude of the effects of natural episodic events and the dynamics of marine ecosystems. The rigor and general applicability of these models in special cases where discharges are close to shore in areas of high productivity or where discharges are proximal to unique habitats is not well established. Along with a general effort to validate the predictive capability of the models, a special effort is needed to determine how well these models address special cases and other contingencies. The need is particularly acute where permit activities involve nearshore coastal or estuarine environments.

In summary, it is possible through existing data and empirical and numerical models to estimate the impact of drilling fluids on specific areas of the marine environment, based on predicted environmental concentrations and effects (determined mainly in the laboratory) at those concentrations. However, the data base for the models should be expanded by (a) monitoring existing and proposed discharges for specific information, and (b) conducting long-term tests at environmentally realistic concentrations to determine community and system effects and chronic effects on organisms representative of areas of biological concern. At present, there is not sufficient evidence that acute toxicity tests, even under optimal conditions, reveal subtle, adverse effects that could occur at the ecosystem level of biological complexity as the result of drilling fluid discharges.

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APPENDIX A

ABSTRACTS OF PUBLISHED PAPERS FROM THE ERL/GB DRILLING FLUIDS RESEARCH PROGRAM, 1976-1984.

ATEMA, JELLE, DALE F. LEAVITT, DIANA E. BARSHAN, AND M. CARMELA CUOMO. 1982. EFFECTS OF DRILLING MUDS ON BEHAVIOR OF THE AMERICAN LOBSTER, HOMARUS AMERICANUS, IN WATER COLUMN AND SUBSTRATE EXPOSURES. CAN. J. FISH. AQUAT. SCI. 39(5):675-689. (ERL,GB X298*).

STUDIES WERE CONDUCTED TO EXPLORE THE EFFECTS OF DRILLING MUDS ON VARIOUS ASPECTS OF LOBSTER BEHAVIOR DIRECTLY RELATED TO SURVIVAL IN THE FIELD. TOXICITY OF DIFFERENT DRILLING MUDS VARIED FROM IMMEDIATELY LETHAL TO ADULT LOBSTERS TO APPARENTLY HARMLESS TO POSTLARVAL STAGES, WITH A VARIETY OF INTERMEDIATE EFFECTS. BOTH THE CHEMICAL TOXICITY IN THE WATER COLUMN AND THE PHYSICAL EFFECTS OF COVERING THE SUBSTRATE WITH DRILLING MUD WERE STUDIED, AND BOTH INTERFERED WITH NORMAL LOBSTER BEHAVIOR. THE STUDIES ARE MAINLY CONCERNED WITH POSTLARVAL LOBSTERS (STAGES VI AND V), I.E., JUST AFTER SETTLING ON THE BOTTOM. THEY WERE TESTED IN 36-D CHRONIC EXPOSURES (7MG/L) AND IN SEMINATURAL AQUARIA WITH 1 MM LAYERS OF DRILLING MUD COVERING THE SUBSTRATE. TOXICITY IN THE WATER COLUMN MANIFESTED ITSELF IN FEEDING AND MOLTING DELAYS, SEVERE DELAYS IN SHELTER CONSTRUCTION, INCREASED WALKING AND SWIMMING, UNPROVOKED TAIL FLIPPING, AND LETHARGY. A NATURAL BAY MUD USED AS A CONTROL CAUSED NO SUCH EFFECTS. PHYSICAL EFFECTS OF SUBSTRATE COVER WERE APPARENT IN EXPERIMENTS WITH 1-, 2-, 4-MM LAYERS OF DRILLING MUD AND SIMILAR LAYERS OF A MIXTURE OF BENTONITE AND BARITE COVERING A NATURAL MUD SUBSTRATE. IN DEPTHS OF 4 MM BOTH KINDS OF SUBSTRATE COVER CAUSED SEVERE DELAYS IN SHELTER CONSTRUCTION AND IN QUALITY OF BURROWS CONSTRUCTED. THUS, SUBSTRATES WITH 4-MM TO PERHAPS AS LITTLE AS 1-MM COVERING OF DRILLING MUD MAY CAUSE INCREASED EXPOSURE OF LOBSTERS TO PREDATORS AND CURRENTS, RESULTING IN THE SUBSTRATE BECOMING UNSUITABLE FOR LOBSTER SETTLING AND SURVIVAL.

AUBLE, GREGOR T., AUSTIN K. ANDREWS, RICHARD A. ELLISON, DAVID B. HAMILTON, RICHARD A. JOHNSON, JAMES E. ROELLE, AND DAVID R. MARMOREK. 1982. RESULTS OF AN ADAPTIVE ENVIRONMENTAL ASSESSMENT MODELING WORKSHOP CONCERNING POTENTIAL IMPACTS OF DRILLING MUDS AND CUTTINGS ON THE MARINE ENVIRONMENT. EPA-600/9-82-019, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 64P.

THE WORKSHOP WAS STRUCTURED AROUND CONSTRUCTION OF A MODEL SIMULATING FATE AND EFFECTS OF DISCHARGES FROM A SINGLE RIG INTO OPEN WATER AREAS OF THE GULF OF MEXICO, AND DISCUSSION OF FACTORS THAT MIGHT PRODUCE DIFFERENT FATE AND EFFECTS IN ENCLOSED AREAS SUCH AS BAYS AND ESTUARIES. THE SIMULATION MODEL WAS COMPOSED OF FOUR CONNECTED SUBMODELS. A DISCHARGE/FATE SUBMODEL DEALT WITH THE DISCHARGE CHARACTERISTICS OF THE RIG AND THE SUBSEQUENT FATE OF DISCHARGED MATERIAL, THREE EFFECTS SUBMODELS THEN CALCULATED BIOLOGICAL RESPONSES AT DISTANCES AWAY FROM THE RIG FOR THE WATER COLUMN, SOFT BOTTOM BENTHOS (ASSUMING THE RIG WAS LOCATED OVER A SOFT BOTTOM ENVIRONMENT), AND HARD BOTTOM BENTHOS (ASSUMING THE RIG WAS LOCATED OVER A HARD BOTTOM ENVIRONMENT). THE MODEL FOCUSED ON DIRECT LINKAGES BETWEEN THE DISCHARGE AND VARIOUS ORGANISMS RATHER THAN ON HOW THE MARINE ECOSYSTEM ITSELF IS INTERCONNECTED.

BOBBIE, R.J., D.C. WHITE, AND P.H. BENSON. 1980. BIOCHEMICAL ANALYSIS OF THE RESPONSE OF THE MARINE MICROFOULING COMMUNITY STRUCTURE TO CLEANING PROCEDURES DESIGNED TO MAINTAIN HEAT TRANSFER EFFICIENCY. IN: PROCEEDINGS OF THE FIFTH INTERNATIONAL CONGRESS OF MARINE CORROSION AND FOULING. L. ARITO, EDITOR, GRAFICAS ORBE S.L., BARCELONA, SPAIN. PP. 391-400. (ERL,GB X184*).

THE MICROFOULING COMMUNITY THAT DEVELOPS IN ALUMINUM PIPES SUBJECT TO FLOWING SEA WATER IS MARKEDLY AFFECTED BY A MECHANICAL CLEANING PROCEDURE EMPLOYED TO MAINTAIN THE EFFICIENT HEAT TRANSFER PROPERTIES NECESSARY IN THE CONDENSER SYSTEM OF THE OCEAN THERMAL ENERGY CONVERSION SYSTEM. SENSITIVE MEASURES OF THE MICROBIAL BIOMASS, SUCH AS THE EXTRACTABLE LIPID PHOSPHATE, THE EXTRACTABLE PALMITIC ACID AND THE TOTAL ORGANIC CARBON SHOW GOOD CORRELATING WITH THE HEAT TRANSFER EFFICIENCY (RF) IN THE EARLY STAGES OF FREE FOULING. AFTER MECHANICAL CLEANING WITH EITHER MANUALLY OPERATED BRUSHES OR THE M.A.N. SYSTEM, MEASURES OF THE TOTAL BIOMASS SUCH AS TOTAL ORGANIC CARBON SHOW REASONABLE CORRELATION TO THE (RF). AFTER CLEANING, MEASURES OF CELLULAR BIOMASS SUCH AS LIPID PHOSPHATE OF LIPID PALMITIC ACID DO NOT CORRELATE WITH THE RF AND THE RATIOS OF TOTAL ORGANIC CARBON. MECHANICAL CLEANING CHANGES THE COMMUNITY STRUCTURE OF THE MICROBES. THE MORPHOLOGY OF THE POPULATION BY SCANNING ELECTRON MICROSCOPY (SEM) REVEALS SELECTIVE REMOVAL OF THE LARGER AND MORPHOLOGICALLY MORE COMPLEX MICROEUKARYOTES WITH RETENTION OF A COMMUNITY ENRICHED IN BACTERIA. EXAMINATION OF THE FATTY ACID COMPOSITION OF THE COMMUNITY SHOWS CLEANING-INDUCED SELECTIVITY NOT ONLY FOR THE BACTERIAL PROKARYOTES BUT FOR A SPECIFIC PROPORTION OF THE BACTERIA. A POPULATION DIFFERENCE BETWEEN THE BACTERIA RETAINED AFTER MANUAL BRUSHING AND CONTINOUS BRUSHING WITH THE M.A.N. SYSTEM CAN ALSO BE DEMONSTRATED. SEM MORPHOLOGY, THE RELATIONSHIP BETWEEN RF AND MEASURES OF TOTAL AND CELLULAR BIOMASS, THE INCREASE IN THE RATIO OF TOTAL ORGANIC CARBON TO CELLULAR BIOMASS AND THE STEADY INCREASE IN A MICROBIAL POPULATION ENRICHED IN LINOLEIC ACID ALL POINT TO AN ACCUMULATION OF EXTRACELLULAR BIOPOLYMER WITH THE CLEANING PROCEDURES. WITH INTERMITTENT CLEANING THE EXOPOLYMER ACCUMULATION ENHANCES THE COLONIZATION BY THE MICROEUKARYOTES BETWEEN THE CLEANING CYCLES.

BOBBIE, RONALD J., AND DAVID C. WHITE. 1980. CHARACTERIZATION OF BENTHIC MICROBIAL COMMUNITY STRUCTURE BY HIGH RESOLUTION GAS CHROMATOGRAPHY OF FATTY ACID METHYL ESTERS. APPL. ENVIRON. MICROBIOL. 39(6):1212-1222. (ERL,GB X009*).

FATTY ACIDS ARE A WIDELY STUDIED GROUP OF LIPIDS OF SUFFICIENT TAXONOMIC DIVERSITY TO BE USEFUL IN DEFINING MICROBIAL COMMUNITY STRUCTURE. THE EXTRAORDINARY RESOLUTION OF GLASS CAPILLARY GAS-LIQUID CHROMATOGRAPHY CAN BE UTILIZED TO SEPARATE AND TENTATIVELY IDENTIFY LARGE NUMBERS OF FATTY ACID METHYL ESTERS DERIVED FROM THE LIPIDS OF ESTUARINE DETRITUS AND MARINE BENTHIC MICROBIOTA WITHOUT THE BIAS OF SELECTIVE METHODS REQUIRING CULTURE OR RECOVERY OF THE MICROBES. THE GAS-LIQUID CHROMATOGRAPHIC ANALYSES ARE BOTH REPRODUCIBLE AND HIGHLY SENSITIVE, AND THE RECOVERY OF FATTY ACIDS IS QUANTITATIVE. THE ANALYSES CAN BE AUTOMATED, AND THE DIAGNOSTIC TECHNIQUE OF MASS SPECTRAL FRAGMENTATION ANALYSIS CAN BE READILY APPLIED. SPLITLESS INJECTION ON GLASS CAPILLARY GAS CHROMATOGRAPHIC COLUMNS DETECTED BY MASS SPECTRAL SELECTIVE ION MONITORING PROVIDES AN ULTRASENSITIVE AND DEFINITIVE MONITORING SYSTEM. RECIPROCAL MIXTURES OF BACTERIA AND FUNGI, WHEN EXTRACTED AND ANALYZED, SHOWED PROGRESSIVE CHANGES OF DISTINCTIVE FATTY ACID METHYL ESTERS DERIVED FROM THE LIPIDS. BY MANIPULATING THE ENVIRONMENT OF AN ESTUARINE DETRITAL MICROBIAL COMMUNITY WITH ANTIBIOTICS AND CULTURE CONDITIONS, IT WAS POSSIBLE TO PRODUCE A COMMUNITY GREATLY ENRICHED IN EUCARYOTIC FUNGI, AS EVIDENCED BY SCANNING ELECTRON MICROSCOPIC MORPHOLOGY. THE FATTY ACID METHYL ESTERS FROM THE LIPIDS IN THE FUNGUS-ENRICHED DETRITUS SHOWED ENRICHMENT OF THE C18 DIENOIC AND THE C18 AND C20 POLYENOIC ESTERS. MANIPULATION OF THE DETRITAL MICROBIOTA THAT INCREASED THE PROCARYOTIC POPULATION RESULTED IN AN ABSENCE OF LARGE STRUCTURES TYPICAL OF FUNGAL MYCELIA OR DIATOMS, AS EVIDENCED BY SCANNING ELECTRON MICROSCOPY, AND A SIGNIFICANTLY LARGER PROPORTION OF ANTEISO- AND ISO-BRANCHED C15 FATTY ACID ESTERS, C17 CYCLOPROPANE FATTY ACID ESTERS, AND THE CIS-VACCENIC ISOMER OF THE C18 MONOENOIC FATTY ACID ESTERS. AS DETERMINED BY THESE TECHNIQUES, A MARINE SETTLING COMMUNITY SHOWED GREATER DIFFERENCES IN BACTERIAL AS CONTRASTED TO MICROEUCARYOTIC POPULATIONS WHEN COMPARED WITH THE MICROBIAL COMMUNITIES OF BENTHIC CORES.

BOBBIE, R.J., J.S. NICKELS, G.A. SMITH, S.D. FAZIO, R.H. FINDLAY, W.M. DAVIS, AND D.C. WHITE. 1981. EFFECT OF LIGHT ON BIOMASS AND COMMUNITY STRUCTURE OF ESTUARINE DETRITAL MICROBIOTA. APPL. ENVIRON. MICROBIOL. 42(1):150-158. (ERL,GB X189*}.

COMPARISON OF ESTUARINE DETRITAL MICROBIOTA GROWN WITH AND WITHOUT LIGHT IN THE ABSENCE OF MACROSCOPIC GRAZING SHOWED SHIFTS IN THE COMMUNITY STRUCTURE THAT ENABLED CORRELATION BETWEEN VARIOUS BIOCHEMICAL MEASURES. ANALYSIS OF THESE BIOCHEMICAL MEASURES SHOWED THAT GROWTH IN LIGHT INDUCES THE SMALLEST INCREASES IN PROCARYOTIC ATTRIBUTES SUCH AS MURAMIC ACID; WALL GLUCOSAMINE; LIPID PHOSPHATE; TOTAL EXTRACTABLE ADENOSINE NUCLEOTIDES; SHORT-BRANCHED, CYCLOPROPANE, AND CISVACCENIC FATTY ACIDS; LIPID GLUCOSE AND MANNOSE; THE INCORPORATION OF ACETATE INTO LIPID; AND THE FORMATION OF DEOXYRIBONUCLEIC ACID FROM THYMIDINE. MEASURES OF THE MICROFAUNA SUCH AS LIPID INOSITOL AND THE Y-LINOLENIC SERIES OF POLYENOIC FATTY ACIDS ALSO INCREASED MINIMALLY IN THE LIGHT-GROWN MICROBIOTA. MEASURES OF SULFOLIPID SYNTHESIS, LIPID GLYCEROL, TOTAL EXTRACTABLE PALMITATE, 18-CARBON POLYENOIC FATTY ACIDS, AND TOTAL POLYENOIC FATTY ACIDS LONGER THAN 20 CARBONS INCREASED 10- TO 15-FOLD IN ALGAE AND FUNGI. CHLOROPHYLL A, LIPID GALACTOSE, AND THE 16- AND 20- CARBON POLYENOIC FATTY ACIDS CHARACTERISTIC OF DIATOMS INCREASED MAXIMALLY IN THE LIGHT. THIS INCREASE OF DIATOM MEASURE CORRELATED WITH THE SHEETS OF DIATOMS DETECTED BY SCANNING ELECTRON MICROSCOPY.

BOOKHOUT, CAZLYN G., ROBERT MONROE, RICHARD FORWARD, AND JOHN D. COSTLOW, JR. 1982. EFFECTS OF SOLUBLE FRACTIONS OF USED LIGHT-WEIGHT LIGNOSULFONATE TYPE MUD AND HEXAVALENT CHROMIUM ON THE COMPLETE LARVAL DEVELOPMENT OF CRABS, RHITHROPANOPEUS HARRISII AND CALLINECTES SAPIDUS. EPA-600/3-82-018, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 64P.
AVAIL. FROM NTIS, SPRINGFIELD, VA: PB82-197203.

THE MUD AQUEOUS FRACTIONS (MAF) AND SUSPENDED PARTICULATE PHASE (SPP) OF LIGNOSULFONATE TYPE MUD WERE NONTOXIC TO THE COMPLETE LARVAL DEVELOPMENT OF RHITHROPANOPEUS HARRISII. FIVE PERCENT MAF AND SPP WERE NOT TOXIC TO CALLINECTES SAPIDUS. DIFFERENTIAL SURVIVAL OF C. SAPIDUS LARVAE OCCURRED FROM 5 TO 50% MAF AND SPP. NO LARVAE REACHED THE 1ST CRAB STAGE IN 100% MAF AND SPP. STATISTICAL ANALYSES OF THE DATA ON SURVIVAL, MORTALITY AND BEHAVIOR ARE PRESENTED. SURVIVAL OF R. HARRISII FROM HATCHING TO 1ST CRAB STAGE OCCURRED IN 1.1 TO 29.1 PPM NA(2)CRO(4). ESTIMATED LC50 FOR COMPLETE ZOEAL DEVELOPMENT WAS 17.8 PP, NA(2)CRO(4) AND WAS 13.7 FOR DEVELOPMENT TO 1ST CRAB STAGE. A CONCENTRATION OF 1.1 PPM WAS NONTOXIC, 7.2 AND 14.5 NA(2)CRO(4) WERE SUBLETHAL AND CONCENTRATIONS OF 29.1 TO 58.1 PPM WERE ACUTELY TOXIC. LOW CONCENTRATIONS OF NA(2)CRO(4) CAUSED AN INCREASE IN SWIMMING SPEED AND HIGH CONCENTRATIONS CAUSED A DECLINE. SURVIVAL OF CALLINECTES SAPIDUS OCCURRED IN 1.1 TO 4.7 NA(2)CRO(4). THE LC50 FOR COMPLETE ZOEAL DEVELOPMENT WAS ESTIMATED TO BE 2.9 PPM AND THE LC50 FOR DEVELOPMENT TO 1ST CRAB STAGE WAS ESTIMATED TO BE 1.0 PPM. STATISTICAL ANALYSES OF THE DATA ON SURVIVAL, DURATION AND MORTALITY OF LARVAE ARE PRESENTED.

BOOKHOUT, C.G., R.J. MONROE, R.B. FORWARD, JR., AND J.D. COSTLOW, JR. 1984. EFFECTS OF SOLUBLE FRACTIONS OF DRILLING FLUIDS ON DEVELOPMENT OF CRABS, RHITHROPANOPEUS HARRISII AND CALLINECTES SAPIDUS. WATER AIR SOIL POLLUT. 21:183-197. (ERL,GB X374*).

THE MUD AQUEOUS FRACTION (MAP) AND SUSPENDED PARTICULATE PHASE (SPP) OF LOW-DENSITY LIGNOSULFONATE TYPE MUD WITH FERROCHROME ADDED WERE NONTOXIC TO LARVAE DURING THE COMPLETE LARVAL DEVELOPMENT OF RHITHROPANOPEUS HARRISII. FIVE PERCENT (5000 PPM, 0.5% V/V MUD IN WATER) MAP AND SPP WERE NOT TOXIC TO CALLINECTES SAPIDUS. SURVIVAL OF C. SAPIDUS LARVAE DECREASED AS CONCENTRATIONS OF MAF AND SPP INCREASED FROM 5% (5000 PPM, 0.5 V/V MUD IN WATER) TO 50% (50,000 PPM, 5% V/V MUD IN WATER). NO LARVAE REACHED THE 1ST CRAB STAGE IN 100% (100000 PPM, 10% V/V MUD IN WATER) MAF AND SPP. STATISTICAL ANALYSIS OF THE DATA ON SURVIVAL, MORTALITY, AND BEHAVIOR ARE PRESENTED. BLUE CRAB LARVAL BEHAVIOR IS AFFECTED BY EXPOSURE TO MAF AND SPP WITH THE GENERAL EFFECT BEING A DECLINE IN SWIMMING SPEED. A SIGNIFICANT REDUCTION WAS ONLY OBSERVED IN 100% MAF BUT WAS NOTICED IN 5, 25, 50, AND 100% SPP.

BOTERO, LEONOR, AND JELLE ATEMA. 1982. BEHAVIOR AND SUBSTRATE SELECTION DURING LARVAL SETTLING IN THE LOBSTER HOMARUS AMERICANUS. J. CRUSTACEAN BIOL. 2(1):59-69. (ERL,GB X399*).

DURING THE MOLT FROM THIRD- TO FOURTH-STAGE, LARVAE OF HOMARUS AMERICANUS METAMORPHOSE INTO THEIR ADULT FORM AND PIGMENTATION. IN THE COURSE OF THE FOURTH STAGE, THEIR PELAGIC LIFE CHANGES TO A BENTHIC EXISTENCE. ARTIFICIAL SUBSTRATE CHOICE EXPERIMENTS AND QUALITATIVE ILLUMINATION EXPERIMENTS SHOW THAT DURING THE EARLY FOURTH STAGE THE PHOTOTACTIC RESPONSE REVERSES FROM POSITIVE TO NEGATIVE. TOGETHER WITH POSITIVE THIGMOTAXIS, THIS RESULTS IN A CHOICE OF DARK CREVICES. AMONG NATURAL SUBSTRATE CHOICES, PREFERENTIAL SETTLEMENT OCCURRED ON MACROALGAL-COVERED ROCKS, FOLLOWED BY ROCKS ON SAND, MUD, AND SAND. MOREOVER, WHEN NO CHOICE WAS GIVEN, SETTLING OCCURRED MOST RAPIDLY ON MACROALGAL-COVERED ROCKS (34 H), FOLLOWED BY SCATTERED ROCKS ON SAND (38 H), AND MUD (62 H); NO SETTLING OCCURRED ON SAND EVEN TWO WEEKS AFTER THE LAST ANIMAL AHD SETTLED ON ALL OTHER SUBSTRATES. THESE ANIMALS CONTINUED TO EXPLORE THE SAND SUBSTRATE WITH DIVES TO THE BOTTOM. ALTHOUGH MUD WAS NOT A PREFERRED SUBSTRATE IN CHOICE TESTS, THE ANIMALS THAT CHOSE MUD AND THOSE THAT WERE PRESENTED ONLY WITH MUD SETTLED SUCCESSFULLY AND WERE IMMEDIATELY EFFICIENT IN THEIR BURROWING BEHAVIOR, CONSTRUCTING U-SHAPED TUNNELS WHEN IN THE CENTER OF THE AQUARIUM WITHOUT USING A PEBBLE OR ROCK AS A STARTING POINT. THESE LABORATORY TESTS CONFIRM FIELD OBSERVATIONS THAT LOBSTERS CAN SUCCESSFULLY EXPLOIT A VARIETY OF SUBSTRATES. THEY SHOW THAT A SUBSTRATE CAN BE MANIPULATED TO MAKE SUITABLE BURROWS.

BRANNON, ANITA C., AND PHILIP J. CONKLIN. 1978. EFFECT OF SODIUM PENTACHLOROPHENATE ON EXOSKELETAL CALCIUM IN THE GRASS SHRIMP, PALAEMONETES PUGIO. IN: PENTACHLOROPHENOL: CHEMISTRY, PHARMACOLOGY, AND ENVIRONMENTAL TOXICOLOGY. K. RANGA RAO, EDITOR, PLENUM PRESS, NEW YORK, NY. PP. 205-211. (ERL,GB X015*).

EXPOSURE OF THE GRASS SHRIMP, PALAEMONETES PUGIO, TO MEDIA CONTAINING SODIUM PENTACHLOROPHENATE (NA-PCP) LED TO AN APPARENT INCREASE IN THE DRY WEIGHT OF EXUVIA AS WELL AS AN INCREASE IN THE TOTAL QUANTITY OF CALCIUM. THE ACTUAL CALCIUM CONCENTRATION (MG CA/MG DRY EXOSKELETON) IN EXUVIA DID NOT VARY SIGNIFICANTLY IN RELATION TO NA-PCP EXPOSURE. WHETHER THE OBSERVED CHANGES IN EXUVIA FROM SHRIMP EXPOSED TO NA-PCP ARE DUE TO A DECREASE IN THE RESORPTION OF THE OLD EXOSKELETON PRECEEDING ECDYSIS REMAINS TO BE CLARIFIED.

BRANNON, ANITA C., AND K. RANGA RAO. 1979. BARIUM, STRONTIUM AND CALCIUM LEVELS IN THE EXOSKELETON, HEPATOPANCREAS AND ABDOMINAL MUSCLE OF THE GRASS SHRIMP, PALAEMONETES PUGIO: RELATION TO MOLTING AND EXPOSURE TO BARITE. COMP. BIOCHEM. PHYSIOL. A COMP. PHYSIOL. 63A:261-274. (ERL,GB X016*).

1. THE BA, SR AND CA LEVELS IN THE EXOSKELETAL AND SOFT TISSUES OF THE GRASS SHRIMP, PALAEMONETES PUGIO, WERE DETERMINED IN RELATION TO ECDYSIS, POSTECDYSIAL MINERALIZATION OF THE CUTICLE AND EXPOSURE TO MEDIA CONTAINING BARITE. 2. THE EXOSKELETAL TISSUES DISCRIMINATED IN FAVOR OF BA AGAINST SR, RELATIVE TO CA. THE HEPATOPANCREAS AND ABDOMINAL MUSCLE DISCRIMINATED IN FAVOR OF BOTH BA AND SR. 3. THE BA/CA AND SR/CA RATIOS OF THE EXOSKELETAL AND SOFT TISSUES VARIED DURING THE MOLT CYCLE. 4. LONG TERM (106 DAYS) EXPOSURE OF SHRIMP TO EITHER SEAWATER (10 % SALINITY) OR SEAWATER CONTAINING 500 MG BARITE/L LED TO A DECREASE IN THE CA CONCENTRATION IN THE ABDOMINAL MUSCLE AND AN INCREASE IN THE CA CONCENTRATION IN THE EXOSKELETON. 5. WHEN EXPOSED TO MEDIA CONTAINING BARITE THE SHRIMP INGESTED PARTICULATE BARITE. 6. THE SHRIMP EXPOSED TO BARITE MEDIA ACCUMULATED HIGHER LEVELS OF BA IN THEIR EXOSKELETAL AND SOFT TISSUES THAN CONTROL SHRIMP IN SEAWATER. THE RELATIVE CONCENTRATIONS OF THE MINERALS IN THE EXUVIA OF BARITE-EXPOSED SHRIMP WERE CA>BA>SR, WHILE THOSE OF CONTROL SHRIMP WERE: CA>SR>BA.

CANTELMO, F.R., AND K.R. RAO. 1978. EFFECT OF PENTACHLOROPHENOL (PCP) ON MEIOBENTHIC COMMUNITIES ESTABLISHED IN AN EXPERIMENTAL SYSTEM. MAR. BIOL. 46(1):17-22. (ERL,GB X029*).

AQUARIA CONTAINING CLEAN SAND RECEIVED A CONTINUOUS SUPPLY OF SEAWATER FROM SANTA ROSA SOUND, FLORIDA, USA, MIXED WITH KNOWN CONCENTRATIONS (7, 76 AND 622 MG 1-1) OF PENTACHLOROPHENOL (PCP). AFTER 9 WEEKS, NEMATODES ACCOUNTED FOR 87% OF THE TOTAL MEIOFAUNA. NEMATODE BIOMASS AND DENSITIES WERE GREATEST IN AQUARIA EXPOSED TO 76 MG PCP 1-1 AND WERE LEAST IN AQUARIA EXPOSED TO 622 MG PCP 1-1. EPISTRATE FEEDERS WERE ABUNDANT IN CONTROL AQUARIA AND AQUARIA EXPOSED TO 7 AND 76 MG PCP 1-1, BUT NOT IN AQUARIA EXPOSED TO 622 MG PCP 1-1. SELECTIVE DEPOSIT FEEDERS WERE NOT ABUNDANT IN THE CONTROL AQUARIA AND AQUARIA EXPOSED TO 7 MG PCP 1-1, BUT COMPRISED 19% OF THE NEMATODES IN AQUARIA EXPOSED TO 76 MG PCP 1-1 AND 61% IN AQUARIA EXPOSED TO 622 MG PCP 1-1.

CANTELMO, ANGELA C., AND K. RANGA RAO. 1978. EFFECTS OF PENTACHLOROPHENOL (PCP) AND 2,4-DINITROPHENOL (DNP) ON THE OXYGEN CONSUMPTION OF TISSUES FROM THE BLUE CRAB, CALLINECTES SAPIDUS, UNDER DIFFERENT OSMOTIC CONDITIONS. COMP. BIOCHEM. PHYSIOL. C COMP. PHARMACOL. 60C(2):215-219. (ERL,GB X028*).

1. THE EFFECTS OF ACCLIMATION TO 300 AND 940 MILLIOSMOLE SEAWATER AND AN ACUTE HYPO-OSMOTIC STRESS ON THE WEIGHT-SPECIFIC OXYGEN CONSUMPTION OF THE GILLS, MUSCLE AND HEPATOPANCREAS OF THE BLUE CRAB, CALLINECTES SAPIDUS, WERE DETERMINED. 2. THE GILL AND MUSCLE TISSUES EXHIBITED AN INCREASE IN OXYGEN CONSUMPTION ON ACCLIMATION OF CRABS TO A LOW SALINITY OR WHEN THE TISSUES WERE SUBJECTED TO AN ACUTE HYPO-OSMOTIC STRESS. SIMILAR TREATMENTS DID NOT ALTER THE OXYGEN CONSUMPTION OF THE HEPATOPANCREAS. 3. AT A CONCENTRATION OF 5 X 10-3 M, PENTACHLOROPHENOL (PCP) AND 2,4-DINITROPHENOL (DNP) CAUSED INHIBITION OF OXYGEN CONSUMPTION IN THE TISSUES EXAMINED. THE EXTENT OF THIS INHIBITION OF OXYGEN CONSUMPTION WAS INDEPENDENT OF THE METABOLIC ACTIVITY OF THE TISSUES.

CANTELMO, FRANK R., AND K. RANGA RAO. 1978. EFFECTS OF PENTACHLOROPHENOL ON THE MEIOBENTHIC NEMATODES IN AN EXPERIMENTAL SYSTEM. IN: PENTACHLOROPHENOL: CHEMISTRY, PHARMACOLOGY, AND ENVIRONMENTAL TOXICOLOGY. K. RANGA RAO, EDITOR, PLENUM PRESS, NEW YORK, NY. PP. 165-174. (ERL,GB X026*).

AQUARIA CONTAINING CLEAN SAND RECEIVED A CONTINUOUS SUPPLY OF SEAWATER FROM SANTA ROSA SOUND, FLORIDA, MIXED WITH KNOWN QUANTITIES OF PCP FOR NINE WEEKS (MAY 10 - JULY 12, 1976) FOR THE FIRST EXPERIMENT AND DOWICIDE G-ST FOR THIRTEEN WEEKS (DECEMBER 27, 1976 - MARCH 28, 1977) FOR THE SECOND EXPERIMENT. THE MEASURED CONCENTRATIONS OF PCP IN THE FORMER EXPERIMENT WERE 776 AND 622 MG/L WHILE THE CONCENTRATIONS AT 1.8, 15.8 AND 161 MG/L WERE USED IN THE LATTER EXPERIMENT. AT EHE END OF EACH EXPERIMENT THE MEIOFAUNA ESTABLISHED IN THE CONTROL AND EXPERIMENTAL AQUARIA WERE EXAMINED. NEMATODES WERE THE DOMINANT GROUP AND AVERAGED 83% OF ALL THE MEIOFAUNA ENCOUNTERED. CONCENTRATIONS OF 1.8, 7 AND 15.8 MG PCP/L DID NOT AFFECT THE BIOMASS AND DENSITY OF NEMATODES. AN INTERMEDIATE CONCENTRATION OF PCP (76 MG/L) CAUSED AN INCREASE IN BIOMASS AND DENSITY OF NEMATODES COMPARED TO CONTROL AQUARIA. HIGHER CONCENTRATIONS OF PCP (161 AND 622 MG/L) CAUSED A DECREASE IN BIOMASS AND DENSITY OF NEMATODES COMPARED TO CONTROL AQUARIA. MARKED CHANGES IN NEMATODE SPECIES COMPOSITION AND SHIFTS IN NEMATODE FEEDING TYPES WERE NOTICED IN THE AQUARIA EXPOSED TO 161 AND 622 MG PCP/L. NEMATODES CLASSIFIED AS EPISTRATE FEEDERS WERE MOST ABUNDANT IN THE CONTROL AQUARIA AND THOSE EXPOSED TO 1.8, 7, 15.8 AND 76 MG PCP/L. DEPOSIT FEEDERS WERE RELATIVELY ABUNDANT AMONG THE NEMATODES IN AQUARIA EXPOSED TO 161 AND 622 MG PCP/L. THE ALTERATIONS IN NEMATODES OBSERVED IN THIS INVESTIGATION APPEARED TO BE DUE TO THE VARIATIONS IN MACROBENTHIC FAUNA AND FOOD (ALGAE) SUPPLY CAUSED BY THE BIOCIDAL EFFECTS OF PCP AND ALSO DUE TO THE TOXIC EFFECTS OF PCP ON MEIOFAUNA.

CANTELMO, ANGELA C., PHILIP J. CONKLIN, FERRIS R. FOX, AND K. RANGA RAO. 1978. EFFECTS OF SODIUM PENTACHLOROPHENATE AND 2,4-DINITROPHENOL ON RESPIRATION IN CRUSTACEANS. IN: PENTACHLOROPHENOL: CHEMISTRY, PHARMACOLOGY, AND ENVIRONMENTAL TOXICOLOGY. K. RANGA RAO, EDITOR, PLENUM PRESS, NEW YORK, NY. PP. 251-263, (ERL,GB X027*).

THE OXYGEN CONSUMPTION OF THE GRASS SHRIMP, PALAEMONETES PUGIO, WAS DETERMINED AT DIFFERENT STAGES OF THE MOLT CYCLE. AT EACH STAGE OF THE MOLT CYCLE, THE OXYGEN CONSUMPTION VARIED IN RELATION TO PERIODS OF ACTIVITY. IN ORDER TO MINIMIZE THE ERRORS IN ESTABLISHING BASAL (CONTROL) RATES OF OXYGEN CONSUMPTION, MEASUREMENTS WERE MADE OVER EXTENDED PERIODS (1 TO 24 HOURS). IN CONTRAST TO THE PREVIOUS REPORTS OF PROGRESSIVE INCREASES IN OXYGEN CONSUMPTION DURING PROECDYSIAL STAGES IN OTHER CRUSTACEANS, WE NOTED SIGNIFICANT INCREASES IN OXYGEN CONSUMPTION JUST PRIOR TO AND DURING THE ACTUAL SHEDDING OF EXOSKELETON (ECDYSIS) IN GRASS SHRIMP. THE EFFECTS OF SODIUM PENTACHLOROPHENATE (NA-PCP) ON OXYGEN CONSUMPTION VARIED DEPENDING ON THE STAGE OF THE MOLT CYCLE, CONCENTRATION OF NA-PCP AND EXTENT OF PRE-EXPOSURE OF SHRIMP TO NA-PCP. AT CONCENTRATIONS OF 1.5 AND 5.0 PPM, NA-PCP DID NOT ALTER THE OXYGEN CONSUMPTION OF SHRIMP IN INTERMOLT AND PROECDYSIAL STAGES OF THE MOLT CYCLE. LATE PROECDYAIAL SHRIMP EXPOSED TO 5.0 PPM NA-PCP EXHIBITED AN INCREASE IN OXYGEN CONSUMPTION IN RELATION TO ECDYSIS TO THE SAME LEVEL AS THAT OF CONTROL SHRIMP. HOWEVER, FOLLOWING ECDYSIS, THE SHRIMP EXPOSED TO 5.0 PPM NA-PCP EXHIBITED A DRAMATIC DECLINE IN OXYGEN CONSUMPTION AND DIED WITHIN THREE HOURS. THIS INCREASED SENSITIVITY DURING THE EARLY POSTECDYSIAL PERIOD APPEARED TO BE RELATED TO AN INCREASE IN THE UPTAKE OF NA-PCP AT THIS STAGE COMPARED TO INTERMOLT AND PROECDYSIAL STAGES. A DECLINE IN OXYGEN CONSUMPTION AS NOTED ABOVE COULD BE INDUCED IN INTERMOLT SHRIMP BY USING HIGHER CONCENTRATIONS OF NA-PCP. EXPOSURE OF SHRIMP TO 10 OR 12 PPM NA-PCP, OR TO 5 PPM FOLLOWED BY 20 PPM NA-PCP CAUSED AN INITIAL INCREASE IN OXYGEN CONSUMPTION AND A SUBSEQUENT DECLINE LEADING TO DEATH. THE SURVIVAL TIME OF INTERMOLT SHRIMP PRETREATED WITH 5 PPM NA-PCP WAS LONGER THAN THAT OF SHRIMP EXPOSED DIRECTLY TO 10 OR 20 PPM NA-PCP. ALTHOUGH 20 PPM 2,4-DINITROPHENOL (DNP) CAUSED AN INITIAL INCREASE IN OXYGEN CONSUMPTION IN INTERMOLT SHRIMP, THIS WAS NOT FOLLOWED BY ANY DECLINE IN OXYGEN CONSUMPTION OR DEATH DURING A 24-HOUR EXPOSURE. THE EFFECTS OF NA-PCP AND DNP ON TISSUE RESPIRATION IN VITRO WERE STUDIED USING THE BLUE CRAB, CALLINECTES SAPIDUS. AT CONCENTRATIONS OF 1 X 10-6 M AND 5 X 10-5 M, THESE COMPOUNDS DID NOT ALTER THE OXYGEN CONSUMPTION OF THE MUSCLE, GILL AND HEPATOPANCREAS. AT A CONCENTRATION OF 5 X 10-3 M, BOTH NA-PCP AND DNP CAUSED AN INHIBITION OF OXYGEN CONSUMPTION OF ISOLATED TISSUES.

CANTELMO, FRANK R., M.E. TAGATZ, AND K. RANGA RAO. 1979. EFFECT OF BARITE ON MEIOFAUNA IN A FLOW-THROUGH EXPERIMENTAL SYSTEM. MAR. ENVIRON. RES. 2(4):301-309. (ERL,GB X151).

THE EFFECTS OF BARITE (94-96% BASO4), A MAJOR CONSTITUENT OF DRILLING MUDS USED IN MARINE OIL DRILLING OPERATIONS, ON MEIOFAUNA WERE STUDIED IN AN EXPERIMENTAL FLOW-THROUGH SYSTEM. AQUARIA CONTAINING SAND OR VARYING PROPORTIONS OF BARITE AND SAND RECEIVED A CONTINUOUS SUPPLY OF UNFILTERED SEAWATER FROM SANTA ROSA SOUND, FLORIDA, FOR TEN WEEKS. AT THE END OF THIS PERIOD THE COMPOSITION, BIOMASS AND VERTICAL DISTRIBUTION OF THE MEIOFAUNA WERE DETERMINED. MOST OF THE MEIOFAUNA (>99%) OCCURRED IN THE HIGHLY AEROBIC UPPER 2 CM PORTION OF THE SUBSTRATUM. ROTIFERA, FORAMINIFERA, HYDROZOA, TURBELLARIA, OSTRACODA, POLYCHAETA AND BIVALVIA DID NOT EXHIBIT SIGNIFICANT DIFFERENCES BETWEEN CONTROL AND EXPERIMENTAL AQUARIA. HOWEVER, THE DENSITIES OF NEMATODA, COPEPODA AND COPEPODA NAUPLII VARIED WITH THE SUBSTRATE COMPOSITION. THE MEIOFAUNAL DENSITIES IN THE AQUARIA CONTAINING 1:10 OR 1:3 MIXTURES OF BARITE AND SAND WERE GREATER THAN THAT IN AQUARIA CONTAINING SAND ALONE. A MARKED DECREASE IN MEIOFAUNAL DENSITY WAS EVIDENT IN AQUARIA CONTAINING 5.5 CM OF SAND COVERED WITH A 0.5 CM LAYER OF BARITE.

CAPUZZO, JUDITH M., AND JENNIFER G. SMITH DERBY. 1982. DRILLING FLUID EFFECTS TO DEVELOPMENTAL STAGES OF THE AMERICAN LOBSTER. EPA-600/4-82-039, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 52P.

LABORATORY EXPERIMENTS WERE CONDUCTED TO EVALUATE THE IMPACT OF DRILLING OPERATIONS FOR OIL EXPLORATION ON POPULATIONS OF THE AMERICAN LOBSTER (HOMARUS AMERICANUS). THE EFFECTS OF USED, WHOLE DRILLING FLUIDS ON THE LARVAL STAGES OF THE LOBSTER WERE ASSESSED IN CONTINUOUS FLOW BIOASSAY EXPERIMENTS. THE FIVE DRILLING FLUIDS TESTED WERE SHOWN TO VARY MARKEDLY IN THEIR TOXICITY, WITH LC-50 VALUES RANGING FROM 74 PPM TO >500 PPM. SUBLETHAL EXPOSURES TO DRILLING FLUIDS RESULTED IN REDUCTIONS IN GROWTH RATES, MOLTING FREQUENCIES, RESPIRATION RATES, FEEDING RATES, AND GROWTH EFFICIENCIES. REDUCED O:N RATIOS AND INCREASED PROTEIN:LIPID RATIOS DEMONSTRATED A CHANGE IN THE ENERGETICS OF THE LARVAL LOBSTERS AS A RESULT OF DRILLING FLUID EXPOSURE. RESULTS SHOW THAT IT IS PRIMARILY THE CHEMICAL AND NOT THE PHYSICAL FEATURES OF DRILLING FLUIDS THAT WERE RESPONSIBLE FOR THE DETRIMENTAL EFFECTS OBSERVED. THE DRILLING FLUIDS TESTED THAT HAD A DIESEL COMPONENT WERE MORE TOXIC THAN THOSE WITHOUT THIS COMPONENT, ALTHOUGH DIRECT CORRELATIONS BETWEEN PERCENT DIESEL AND RELATIVE TOXICITY COULD NOT BE MADE. THE PHENOL AND METAL CONTENT OF THE DRILLING FLUIDS MAY HAVE ALSO CONTRIBUTED TO THEIR TOXICITY. FIELD DISPERSION STUDIES ON DRILLING FLUIDS ARE DISCUSSED IN TERMS OF POTENTIAL IMPACT AREAS.

CONKLIN, PHILIP J., AND K. RANGA RAO. 1978. TOXICITY OF SODIUM PENTACHLOROPHENATE (NA-PCP) TO THE GRASS SHRIMP, PALAEMONETES PUGIO, AT DIFFERENT STAGES OF THE MOLT CYCLE. BULL. ENVIRON. CONTAM. TOXICOL. 20(2):275-279. (ERL,GB X021*).

PENTACHLOROPHENOL (PCP) AND ITS SALT, SODIUM PENTACHLOROPHENATE (NA-PCP) ARE WIDELY USED AS BIOCIDES (BEVENUE AND BECKMAN 1967). PREVIOUS INVESTIGATIONS INDICATE THAT ADULT CRUSTACEANS ARE MORE TOLERANT THAN FISH TO PCP AND NA-PCP (GOODNIGHT 1942; KAILA AND SAARIKOSKI 1977). THE TOXICITY DATA FOR CRUSTACEANS ARE BASED ON SHORT TERM (USUALLY 96 HOURS OR LESS) BIOASSAYS ON INDIVIDUALS WHOSE PHYSIOLOGICAL STATUS IN RELATION TO THE MOLT CYCLE WAS UNKNOWN. SINCE CHANGES IN THE PERMEABILITY OF CUTICLES ARE EXPECTEDF TO OCCUR IN RELATION TO THE CYCLIC SHEDDING, SECRETION AND HARDENING OF THE EXOSKELETON IN CRUSTACEANS (PASSANO 1960) IT IS IMPORTANT TO EVALUATE THE TOXICITY OF PESTICIDES AT KNOWN STAGES OF THE MOLT CYCLE. ALTHOUGH THERE ARE REPORTS OF AN APPARENT INCREASE IN THE SENSITIVITY OF ADULT CRUSTACEANS DURING OR SOON AFTER MOLTING (ECDYSIS) TO TOXICANTS SUCH AS COPPER (HUBSCHMAN 1967), AROCLOR 1254 (DUKE ET AL. 1970; NIMMO ET AL. 1971) AND METHOXYCHLOR (ARMSTRONG ET AL. 1976) THERE HAVE BEEN NO TOXICOLOGICAL EVALUATIONS IN RELATION TO THE DIFFERENT STAGES OF THE MOLT CYCLE. THE CRUSTACEAN MOLT CYCLE IS DIVIDED INTO FIVE MAJOR STAGES (A THROUGH E) AND SEVERAL SUBSTAGES (DRACH 1939) WHICH CAN BE IDENTIFIED BY DISTINCT MORPHOLOGICAL CRITERIA. THE AIM OF THIS INVESTIGATION WAS TO EVALUATE THE TOXICITY OF NA-PCP TO THE GRASS SHRIMP, PALAEMONETES PUGIO, AT SPECIFIC STAGES OF THE MOLT CYCLE USING STANDARD 96 HOUR BIOASSAYS.

CONKLIN, PHILIP J., AND K. RANGA RAO. 1978. TOXICITY OF SODIUM PENTACHLOROPHENATE TO THE GRASS SHRIMP, PALAEMONETES PUGIO, IN RELATION TO THE MOLT CYCLE. IN: PENTACHLOROPHENOL: CHEMISTRY, PHARMACOLOGY, AND ENVIRONMENTAL TOXICOLOGY. K. RANGA RAO, EDITOR, PLENUM PRESS, NEW YORK, NY. PP. 181-192. (ERL,GB X040*).

THE TOXICITY OF SODIUM PENTACHLOROPHENATE (NA-PCP) TO THE GRASS SHRIMP, PALAEMONETES PUGIO, WAS EVALUATED AT DIFFERENT STAGES OF THE MOLT CYCLE. IN 96-HOUR BIOASSAYS, THE SHRIMP IN LATER STAGES OF THE PROECDYSIAL PERIOD EXHIBITED A GREATER SENSITIVITY TO NA-PCP THAN THAT EXHIBITED BY SHRIMP IN THE INTERMOLT AND EARLY PROECDYSIAL STAGES OF THE MOLT CYCLE. THE SHRIMP IN LATER PROECDYSIAL STAGES GENERALLY MOLTED (UNDERWENT ECDYSIS) DURING THE 96-HOUR TEST PERIOD AND DIED SHORTLY AFTER ECDYSIS. THE 96-HOUR LC50 VALUE OBTAINED FOR THESE SHRIMP (0.436 PPM) IS THE LOWEST OF ALL THE LC50 VALUES REPORTED PREVIOUSLY FOR ADULT CRUSTACEANS AND IS COMPARABLE TO THOSE FOR FISH AND LARVAL CRUSTACEANS. THE INCREASED SENSITIVITY TO NA-PCP DURING THE EARLY POSTECDYSIAL PERIOD WAS ALSO APPARENT IN A LONG-TERM (66 DAYS) TEST. THE OBSERVED POSTECDYSIAL MORTALITY OF SHRIMP EXPOSED TO 1.0 PPM NA-PCP WAS NOT DEPENDENT ON THE DURATION OF EXPOSURE OF SHRIMP TO NA-PCP DURING THE PROECDYSIAL PERIOD. STUDIES WITH 14C-PCP INDICATE THAT AN ABRUPT INCREASE IN THE UPTAKE OF PCP DURING THE PERIOD SHORTLY AFTER ECDYSIS MAY CAUSE INCREASED MORTALITIES DURING THIS PERIOD.

CONKLIN, PHILIP J., DANIEL G. DOUGHTIE, AND K. RANGA RAO. 1980. EFFECTS OF BARITE AND USED DRILLING MUDS ON CRUSTACEANS, WITH PARTICULAR REFERENCE TO THE GRASS SHRIMP, PALAEMONETES PUGIO. IN: SYMPOSIUM: RESEARCH ON ENVIRONMENTAL FATE AND EFFECTS OF DRILLING FLUIDS AND CUTTINGS, JAN. 21-24, 1980, LAKE BUENA VISTA, FL., VOL. 2. AMERICAN PETROLEUM INSTITUTE, WASHINGTON, DC. PP. 912-943. (ERL,GB X226*).

WHEN EXPOSED TO MEDIA CONTAINING BARITE OR USED DRILLING MUD, THE GRASS SHRIMP PALAEMONETES PUGIO INGESTED THE SETTLED BARITE AND DRILLING MUD PARTICLES. ULTRASTRUCTURAL STUDIES ON THE MIDGUT OF SHRIMP EXPOSED FOR A 30-DAY PERIOD TO 100 OR 500 PPM BARITE-CONTAINING MEDIA SHOWED THAT PROLONGED INGESTION OF BARITE CAUSES MARKED PERTURBATIONS IN THE POSTERIOR MIDGUT EPITHELIUM. WHAT EFFECTS THE INGESTION OF WHOLE DRILLING MUD PARTICLES HAS ON THE DIGESTIVE EPITHELIA REMAINS TO BE STUDIED. DEPENDING ON THE TYPE OF PARTICULATE MATERIALS AVAILABLE IN THE MEDIUM AT THE SAME TIME OF MOLTING, THE GRASS SHRIMP INCORPORATED SAND GRAINS, BARITE, OR DRILLING MUD PARTICLES INTO ITS STATOCYCTS--THE EQUILIBRIUM RECEPTORS LOCATED IN THE BASAL ANTENNULAR SEGMENT. WHETHER THE PHYSIOLOGY OF THESE SENSE ORGANS WOULD BE AFFECTED BY THE INCORPORATION OF BARITE AND DRILLING MUD PARTICLES MERITS FURTHER INVESTIGATION. A COMPARATIVE STUDY OF THE TOXICITY OF 18 DIFFERENT SAMPLES OF USED (SPENT) DRILLING MUDS FROM AN EXPLORATORY DRILLING RIG IN A LOCAL ESTUARY REVEALED THAT, DURING A 96-HR TEST PERIOD, NONE OF THE MUDS WAS TOXIC TO INTERMOLT GRASS SHRIMP AT MUD CONCENTRATION OF 1000 UL/L (10 AND 100 PPM). BUT AS A CONCENTRATION OF 1000 UL/L (1000 PPM), SIX OF THESE MUDS CAUSED 30 TO 60% MORTALITY OF INTERMOLT GRASS SHRIMP DURING A 96-HR TEST PERIOD, WHILE ONE MUD CAUSED 100% MORTALITY. TOXICITY TESTS WITH MOLTING GRASS SHRIMP YIELDED LC 50 VALUES OF 363 TO 739 UL/L FOR FIVE OF THE MUD SAMPLES. A FLOW-THROUGH SYSTEM WAS EMPLOYED FOR ASSESSING THE TOXICITY OF DRILLING MUD DURING THE MOLT CYCLE OF PALAEMONETES AND THE LIFE CYCLE OF MYSIDOPSIS BAHIA. MYSIDS ARE FOUND TO BE MORE SENSITIVE THAN GRASS SHRIMP TO DRILLING MUD EXPOSURE. IN LIFE CYCLE TESTS WITH MYSIDS, THE LC 50 FOR ONE OF THE MUDS WAS 50 UL/L. THE LC 50 VALUES OBTAINED WITH TESTS INVOLVING MOLTING GRASS SHRIMP AND MYSIDS ARE SEVERAL MAGNITUDES LOWER THAN THE PREVIOUSLY REPORTED LC 50 VALUES FOR FISHES. THESE RESULTS EMPHASIZE THE NEED FOR EMPLOYING SENSITIVE ORGANISMS AND LONG-TERM TESTS FOR ASSESSING THE TOXIC AND SUBLETHAL EFFECTS OF USED DRILLING MUDS.

CONKLIN, PHILIP J., AND K. RANGA RAO. 1982. EFFECTS OF TWO DITHIOCARBAMATES ON THE GRASS SHRIMP, PALAEMONETES PUGIO: MOLT-RELATED TOXICITY AND INHIBITION OF LIMB REGENERATION. ARCH. ENVIRON. CONTAM. TOXICOL. 11(4):431-435. (ERL,GB X210*).

THE EFFECTS OF TWO DITHIOCARBAMATE FORMULATIONS (AQUATREAT DNM-30 AND BUSAN 85) ON THE INITIATION AND PROGRESSION OF LIMB REGENERATION FOLLOWING THE REMOVAL OF THE LEFT FIFTH WALKING LEG (PEREIOPOD) WERE STUDIED WITH THE ESTUARINE GRASS SHRIMP, PALAEMONETES PUGIO. EXPOSURE TO EITHER AQUATREAT DNM-30 OR BUSAN 85 AFFECTED BOTH THE INITIATION AND PROGRESSION OF LIMB REGENERATION; THE SHRIMP EXHIBITED DOSE-RELATED INHIBITION OF REGENERATIVE GROWTH. THE RESULTANT EC(50) VALUES FOR INHIBITION OF REGENERATIVE LIMB GROWTH WERE WELL BELOW THE MEDIAN LETHAL CONCENTRATIONS (LC(50)S) FOR GRASS SHRIMP. IN TESTS WITH MOLTING GRASS SHRIMP, BUSAN 85 WAS MORE ACUTELY TOXIC THAN AQUATREAT DNM-30.

CONKLIN, P.J., D. DRYSDALE, D.G. DOUGHTIE, K.R. RAO, J.P. KAKAREKA, T.R. GILBERT, AND R.F. SHOKES. 1983. COMPARATIVE TOXICITY OF DRILLING MUDS: ROLE OF CHROMIUM AND PETROLEUM HYDROCARBONS. MAR. ENVIRON. RES. 10(2):105-125. (ERL,GB X398*).

SAMPLES OF USED DRILLING MUDS COLLECTED DURING THE COURSE OF A SINGLE WELL DRILLING OPERATION EXHIBITED DIFFERENT DEGREES OF ACUTE TOXICITY TO SHEEPSHEAD MINNOWS AND GRASS SHRIMP. FOR MOLTING GRASS SHRIMP (PALAEMONETES PUGIO), THE 96-H LC50'S WERE 360 TO 14,560 PPM (UL/LITER); MANY OF THESE VALUES WERE CONSIDERABLY LOWER THAN THOSE REPORTED FROM PREVIOUS DRILLING MUD ASSAYS. HOWEVER, WHEN SOME OF THE MUDS USED IN THIS STUDY WERE TESTED ON SHEEPSHEAD MINNOWS (CYPRINODON VARIEGATUS) THE RESULTING 96-H LC50'S (6,300 TO 100,000 PPM) WERE WELL WITHIN THE RANGE OF PREVIOUSLY REPORTED VALUES. ALTHOUGH A NUMBER OF THE DRILLING MUD SAMPLES HAD RELATIVELY HIGH AMOUNTS OF CHROMIUM DUE TO THE ADDITION OF SODIUM CHROMATE, THERE WAS A LOW CORRELATION BETWEEN CHROMIUM CONCENTRATION AND TOXICITY. IN ONLY THREE DRILLING MUDS COULD CHROMIUM CONTENT ALONE ACCOUNT FOR THE OBSERVED TOXICITIES. FURTHERMORE, CHEMICAL /ANALYSIS REVEALED THE PRESENCE OF NO. 2 FUEL OIL-LIKE PETROLEUM HYDROCARBONS IN THE MUD SAMPLES. BASED ON THE RESULTS OF TOXICITY TESTS WITH NO. 2 FUEL OIL AND THE CONCENTRATIONS OF OIL PRESENT IN THE MUDS, THE TOXICITY OF THE MUD SAMPLES TO GRASS SHRIMP APPEARS TO BE LARGELY ATTRIBUTABLE TO THE PETROLEUM HYDROCARBON CONTENT.

CONKLIN, PHILIP J., AND K. RANGA RAO. 1983. COMPARATIVE TOXICITY OF WASTE DRILLING FLUIDS TO A CRUSTACEAN (PALAEMONETES PUGIO) AND A FISH (CYPRINODON VARIEGATUS) (ABSTRACT). IN: PROCEEDINGS OF THE NINTH ANNUAL AQUATIC TOXICITY WORKSHOP: NOV. 1-5, 1982, CAN. TECH. REP. FISH. AQUAT. SCI. 1163. W. C. MCKAY, EDITOR, DEPT. OF FISHERIES AND OCEANS, OTTAWA, ONTARIO. PP. 205. (ERL,GB X476*).

THE ACUTE TOXICITY OF A SERIES OF 18 DRILLING FLUIDS (MUDS) FROM AN EXPLORATORY DRILLING OPERATION WAS EVALUATED IN TESTS USING 28-DAY OLD JUVENILE SHEEPSHEAD MINNOWS (CYPRINODON VARIEGATUS) AND GRASS SHRIMP (PALAEMONTES PUGIO.) GRASS SHRIMP THAT MOLTED DURING THE TESTS WERE ESPECIALLY SENSITIVE TO THE DRILLING MUDS; THE 96-HR LC50S (363 TO 14,565 PPM MUD BY VOLUME) ARE CONSIDERABLY LOWER THAN THE PREVIOUSLY REPORTED TOXICITY VALUES FOR DRILLING MUDS. SHEEPSHEAD MINNOWS WERE CONSIDERABLY LESS SENSITIVE TO THE MUDS THAN WERE GRASS SHRIMP. ALTHOUGH A NUMBER OF THE DRILLING MUDS CONTAINED RELATIVELY HIGH AMOUNTS OF CHROMIUM, IN MOST INSTANCES THE OBSERVED TOXICITIES DID NOT APPEAR TO BE ATTRIBUTABLE TO CHROMIUM ALONE. HOWEVER, THERE WAS A SIGNIFICANT CORRELATION BETWEEN THE AMOUNT OF OIL PRESENT IN THE MUDS AND THEIR TOXICITY TO GRASS SHRIMP.

CRAWFORD, RICHARD B., AND JONATHAN D. GATES. 1981. DRILLING FLUID EFFECTS ON TELEOST AND ECHINODERM DEVELOPMENT. BULL. MT. DESERT ISL. BIOL. LAB. 20:10-14. (ERL,GB X242*).

AS A CONSEQUENCE OF PETROLEUM DRILLING OFFSHORE, LARGE QUANTITIES OF DRILLING FLUIDS (MUDS) ARE INTRODUCED INTO THE ENVIRONMENT. THESE DRILLING FLUIDS ARE AQUEOUS SUSPENSIONS OF A VARIETY OF COMPONENTS PUMPED DOWN THE CENTER OF THE DRILL BIT. THE FLUID COMPOSITION IS VARIED AS NEEDS OF THE DRILLING OPERATION ARE ENCOUNTERED, SUCH AS LUBRICATION, COOLING, ANTIBACTERIAL ACTION, SUSPENSION OF DRILL CUTTINGS, PREVENTION OF INTRUSION OF SEAWATER INTO THE BORE HOLE, AND CAPTURE OF H2S. THE IMPACT OF DRILLING FLUIDS ON MARINE AND ESTUARINE ANIMALS ARE DISCUSSED. THIS DISCHARGE CAN AMOUNT TO SIGNIFICANTLY LARGE QUANTITIES (E.G., 2,000 TONS PER HOLE) IN THE VICINITY OF A DRILLING PLATFORM.

CRAWFORD, RICHARD B., AND JONATHAN D. GATES. 1981. EFFECTS OF A DRILLING FLUID ON THE DEVELOPMENT OF A TELEOST AND AN ECHINODERM. BULL. ENVIRON. CONTAM. TOXICOL. 26(2):207-212. (ERL,GB X297*).

THE DATA ON EFFECTS OF DRILLING FLUID ON EMBRYO DEVELOPMENT IN FUNDULUS AND A SAND DOLLAR REPRESENT AN INITIAL SURVEY ON VERY GENERAL ASPECTS OF EMBRYOGENESIS. IT IS CLEAR THAT THIS DRILLING FLUID SAMPLE CONTAINS TOXIC MATERIAL, AFFECTING THE DEVELOPMENT OF THE TELEOST AND THE FERTILIZATION AND DEVELOPMENT OF THE SAND DOLLAR. IT SHOULD BE NOTED THAT NO ONE SAMPLE IS REPRESENTATIVE OF ALL DRILLING FLUIDS. THE COMPONENTS OF THE FLUID ARE ALTERED TO MEET THE MOMENTARY NEEDS OF THE DRILLING OPERATION. FOR EXAMPLE, THIS SAMPLE IS MODERATELY HIGH IN CHROMIUM (2400 MG/G), ZINC (163 MG/G) AND LEAD (66.6 MG/G) BUT LOW IN BARIUM CONTENT (7.31%). THE RANGE OF VARIABILITY AMONG DRILLING FLUIDS FOR THESE COMPONENTS CAN BE FOUND TO BE APPROXIMATELY 50 TO 5500 MG/G FOR CR, 50 TO 600 MG/G FOR ZN, 25 TO 120 MG/G FOR PB, AND 1 TO 35% FOR BA. THIS VARIABILITY IS NOT MENTIONED TO SUGGEST THE ACTIVE COMPONENTS, OF WHICH WE HAVE NO KNOWLEDGE, BUT ONLY TO ILLUSTRATE THE "NON-TYPICAL" NATURE OF ANY ONE SAMPLE.

CRAWFORD, RICHARD B. 1983. EFFECTS OF DRILLING FLUIDS ON EMBRYO DEVELOPMENT. EPA-600/3-83-021, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 30P.

TOXICITY OF USED DRILLING FLUIDS TO EMBRYO DEVELOPMENT WAS INVESTIGATED TO ASCERTAIN THE LIMITS OF SAFE USAGE OF THESE FLUIDS IN MARINE ENVIRONMENTS. EMBRYOS USED AS TEST SYSTEMS WERE OF THE TELEOST, FUNDULUS HETEROCLITUS, AND FOUR ECHINODERMS ECHINARACHNIUS PARMA, STRONGYLOCENTROTUS PURPURATUS, LYTECHINUS PICTUS, LYTECHINUS VARIEGATUS. THE DRILLING FLUIDS TESTED CAME FROM VARIOUS SOURCES; 24 DIFFERENT SAMPLES WERE EVALUATED. IN ADDITION, SEVERAL COMMERCIAL DRILLING FLUID COMPONENTS WERE EXAMINED IN THE TEST SYSTEMS INCLUDING A SYNTHETIC REFERENCE MUD. STUDIES DEMONSTRATED THAT NO SINGLE DRILLING FLUID IS "TYPICAL" AND THAT THE QUANTITATIVE EFFECTS OF EMBRYOS VARY CONSIDERABLY FROM ONE FLUID TO ANOTHER. SOME DRILLING FLUIDS ARE QUITE TOXIC TO ONE OR MORE OF THE EMBRYO SYSTEMS, REQUIRING DILUTIONS OF OVER 10(5) TO BECOME "SAFE". OTHERS ARE RELATIVELY INNOCUOUS, REQUIRING VERY LITTLE DILUTION TO ACHIEVE A CONCENTRATION IN WHICH EMBRYO DEVELOPMENT CAN PROCEED NORMALLY. ALSO, THE EFFECTS ON DEVELOPMENT SHOW VARIATION FROM ONE FLUID TO ANOTHER, THUS INDICATING THAT A VARIETY OF COMPONENTS OR COMPOUNDS ARE RESPONSIBLE FOR TOXIC MANIFESTATIONS.

D'ASARO, CHARLES N. 1982. CYCLING OF XENOBIOTICS THROUGH MARINE AND ESTUARINE SEDIMENTS. EPA-600/3-82-074, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 40P.

THE RESULTS OF FIVE BROADLY DEFINED PROJECTS ARE REPORTED: CYCLING OF XENOBIOTICS WAS STUDIED WITH A PHOTO-BIOASSAY SYSTEM, THAT USED TIME-LASPE PHOTOGRAPHY TO EVALUATE EFFECTS OF KEPONE AND SODIUM PENTACHLOROPHENATE ON FEEDING ACTIVITY OF THE LUGWORM, ARENICOLA CRISTATA. RADIO-LABELED METHYL PARATHION WAS USED TO DEMONSTRATE FATE AND EFFECT IN MICROCOSMS INHABITED BY LUGWORMS. UPTAKE AND DEPURATION OF CHRYSENE BY LUGWORMS WAS EVALUATED IN A FLOW-THROUGH SYSTEM. A TOXIC SEDIMENT BIOASSAY SYSTEM WAS DEVELOPED TO PROVIDE A MEANS TO TEST EFFECTS OF DREDGE SPOIL. THE SYSTEM INCLUDED MICROCOSMS THAT HELD MYSID SHRIMP, MYSIDOPSIS BAHIA; OYSTERS, CRASSOSTREA VIRGINICA; AND LUGWORMS, ARENICOLA CRISTATA. CRITERIA OF EFFECT WERE SURVIVAL OF MYSIDS, SHELL DEPOSITION AND BIOACCUMULATION BY OYSTERS, SUBSTRATE REWORKING AND BIOACCUMULATION BY LUGWORMS, AND SETTLEMENT OF ZOOPLANKTON. KEPONE-SORBED SEDIMENT AND DREDGE SPOIL FROM JAMES RIVER AND HOUSTON SHIP CANAL WERE TESTED FOR 28 DAYS. LONG-TERM TESTS (100 DAYS), WITH THE SAME SYSTEMS, WERE USED TO EVALUATE EFFECTS OF A SPECIFIC DRILLING MUD FROM AN ACTIVE EXPLORATORY PLATFORM. PREDATOR-PREY TESTS OF SUBLETHAL EFFECTS OF XENOBIOTICS DEMONSTRATED EFFECT IN ONE-PREY AND TWO-PREY SYSTEMS. THE EFFECTS OF METHYL PARATION ON PREDATOR-PREY RELATIONSHIPS BETWEEN GRASS SHRIMP, PALAEMONETES PUGIO; JUVENILE SHEEPHEAD MINNOWS, CYPRINODON VARIEGATUS; AND GULF KILLIFISH, FUNDULUS GRANDIS, WERE DEMONSTRATED. THE EFFECTS OF METHYL PARATHION ON THE PREDATOR PREY RELATIONSHIPS BETWEEN PALAEMONETES PUGIO, AND PINFISH, LAGODON RHOMOBIODES, WAS ALSO DEMONSTRATED. A METHOD THAT COULD BE USED TO EVALUATE EFFECTS XENOBIOTICS ON PREDATOR-PREY RELATIONSHIPS BETWEEN CRYPTICALLY SHADED FLOUNDER AND PINFISH PREY WAS DEVELOPED. EVALUATION OF SUBLETHAL EFFECTS, SUCH AS AVOIDANCE OF POLLUTION GRADIENTS, WAS STUDIED IN A TROUGH-TYPE AVOIDANCE-REPSONSE SYSTEM. THE SYSTEM RECORDED REPSONSES AUTOMATICALLY AND INDEPENDENTLY OF AN OBSERVER. TESTS WITH PINFISH DEMONSTRATED THAT THEY WILL AVOID CHLORINE-PRODUCED OXIDANTS. THE SYSTEM WAS MODIFIED TO DEMONSTRATED TOXICANT-INDUCED CHANGES IN CYCLIC BURROWING ACTIVITY BY PINK SHRIMP, PENAEUS DUORARUM, EXPOSED TO METHYL PARATHION. USEFULNESS OF SMALL-SCALE MICROCOSMS WAS EVALUATED BY DEVELOPING METHODS TO CULTURE POLYCHAETES AND CRUSTACEANS. VARIOUS ASPECTS OF THE BIOLOGY OF SELECTED SPECIES WERE STUDIED.

DAVIS, W.M., AND D.C. WHITE. 1980. FLUOROMETRIC DETERMINATION OF ADENOSINE NUCLEOTIDE DERIVATIVES AS MEASURES OF THE MICROFOULING, DETRITAL AND SEDIMENTARY MICROBIAL BIOMASS AND PHYSIOLOGICAL STATUS. APPL. ENVIRON. MICROBIOL. 40(3):539-548. (ERL,GB X186*).

ADENOSINE, ADENINE, CYCLIC ADENOSINE MONOPHOSPHATE (AMP), AMP, NICOTINAMID ADENINE DINUCLEOTIDE, ADENOSINE DIPHOSPHATE, AND ADENOSINE TRIPHOSPHATE (ATP) WERE RECOVERED QUANTITATIVELY FROM AQUEOUS PORTIONS OF LIPID EXTRACTS OF MICROFOULING, DETRITAL, AND SEDIMENTARY MICROBIAL COMMUNITIES. THESE COULD BE DETECTED QUANTITATIVELY IN THE PICOMOLAR RANGE BY FORMING THEIR 1-N6-ETHENO DERIVATIVES AND ANALYZING BY HIGH-PRESSURE LIPID CHROMATOGRAPHY WITH FLOURESCENT DETECTION. LIPID EXTRACTION AND SUBSEQUENT ANALYSIS ALLOWED THE SIMULTANEOUS MEASUREMENT OF THE MICROBIAL COMMUNITY STRUCTURE, TOTAL MICROBIAL BIOMASS WITH THE QUANTITATIVE RECOVERY OF THE ADENINE-CONTAINING CELLULAR COMPONETS, WHICH WERE PROTECTED FROM ENZYMATIC DESTRUCTION. THIS EXTRACTION AND FLOURESCENT DERIVATIZATION METHOD SHOWED EQUIVALENCY WITH THE LUCIFERIN-LUCIFERASE METHOD FOR BACTERIAL ATP MEASUREMENTS. QUICK-FREEZING SAMPLES IN THE FIELD WITH DRY ICE-ACETONE PRESERVED THE ATP AND ENERGY CHARGE (A RATIO OF ADENOSINE NUCLEOTIDES) FOR ANALYSIS AT REMOTE LABORATORIES. THE METABOLIC LABILITY OF ATP IN ESTUARINE DETRITAL AND MICROFOULING COMMUNITIES, AS WELL AS BACTERIAL MONOCULTURES OF CONSTANT BIOMASS, SHOWED ATP TO BE A PRECARIOUS MEASURE OF BIOMASS UNDER SOME CONDITIONS. COMBINATIONS OF ADENOSINE AND ADENINE NUCLEO-TIDES GAVE BETTER CORRELATIONS WITH MICROBIAL BIOMASS MEASURED AS EXTRACTABLE LIPID PHOSPHATE IN THE DETRITAL AND MICROFOULING MICROBIAL COMMUNITIES THAN DID ATP ALONE. STRESSES SUCH AS ANOXIA OF FILTERATION ARE REFLECTED IN THE RAPID ACCUMULATION OF INTRACELLULAR ADENOSINE AND THE EXCRETION OF ADENOSINE AND AMP INTO THE SURROUNDING MILIEU. INCREASES IN AMP AND ADENOSINE MAY PROVE TO BE MORE SENSITIVE INDICATORS OF METABOLIC STATUS THAN THE ENERGY CHARGE.

DERBY, CHARLES D., AND JELLE ATEMA. 1981. INFLUENCE OF DRILLING MUDS ON THE PRIMARY CHEMOSENSORY NEURONS IN WALKING LEGS OF THE LOBSTER, HOMARUS AMERICANUS. CAN. J. FISH. AQUATIC SCI. 38(3):268-274. (ERL,GB X241*). AVAIL. FROM NTIS, SPRINGFIELD, VA: PB82-128190.

THE EFFECTS OF WHOLE DRILLING MUDS ON THE NORMAL ACTIVITY OF WALKING LEG CHEMOSENSORY NEURONS WERE EXAMINED USING EXTRACELLULAR NEUROPHYSIOLOGICAL RECORDING TECHNIQUES. EXPOSURE OF LEGS FOR 3-5 MIN TO 10-MG/L DRILLING MUD SUSPENDED IN SEAWATER ALTERED RESPONSES TO FOOD ODORS OF 29% OF THE CHEMORECEPTORS EXAMINED (DATA POLLED FOR THE TWO DRILLING MUDS TESTED); SIMILAR EXPOSURE TO 100-MG/L DRILLING MUD RESULTED IN INTERFERENCE WITH 44% OF ALL RECEPTORS STUDIES. THE EFFECTS OF BOTH OF THESE CONCENTRATIONS ARE STATISTICALLY SIGNIFICANT, ALTHOUGH THEY ARE NOT DIFFERENT FROM EACH OTHER. INTERFERENCE WAS USUALLY MANIFESTED AS A MARKED REDUCTION IN THE NUMBER OF ACTION POTENTIALS IN A RESPONSE. IN ONE PREPARATION, THE EXPOSURE TO DRILLING MUD CAUSED A CHANGE IN THE TEMPORAL PATTERN OF THE SPIKES WITHOUT AFFECTING THE TOTAL NUMBER OF SPIKES. OTHER CHEMOSENSORY NEURONS WERE EXCITED BY 10-MG/L DRILLING MUD ITSELF. HOWEVER, NOT ALL CHEMORECEPTORS ARE AFFECTED BY THESE DRILLING MUDS SINCE RESPONSES TO FEEDING STIMULI WERE RECORDED FROM THE LEGS OF LOBSTERS THAT HAD BEEN EXPOSED TO DRILLING MUD FOR 4-8 D BEFORE THE NEUROPHYSIOLOGICAL EXPERIMENTS.

DERBY, CHARLES D., AND JELLE ATEMA. 1982. NARROW-SPECTRUM CHEMORECEPTOR CELLS IN THE WALKING LEGS OF THE LOBSTER HOMARUS AMERICANUS: TASTE SPECIALIST. J. COMP. PHYSIOL. A SENS. NEURAL. BEHAV. PHYSIOL. 146(2):181-189. (ERL,GB X341*).

THE PRESENT STUDY DESCRIBES THE SPECIFICITY OF CHEMORECEPTORS IN THE WALKING LEGS OF THE LOBSTER HOMARUS AMERICANUS. THE RESULTS INDICATE THAT THE PERIPHERAL CODING SYSTEM OF THIS SPECIES IS BASED AT LEAST IN PART ON NARROWLY-TUNED CHEMORECEPTOR CELLS, WHICH REPRESENTS ONE OF THE MOST EXTREME CASES TO DATE OF A CHEMOSENSORY SYSTEM BASED ON LABELED LINE CODING. THE CHEMORECEPTORS IN THE LEGS OF LOBSTERS FUNCTION IN THE LOCALIZATION AND HANDLING OF FOOD (DERBY AND ATEMA 1982B). MULTI-UNIT NEUROPHYSIOLOGICAL ANALYSIS FO THESE RECEPTORS HAS DEMONSTRATED THAT CERTAIN AMINO ACIDS AND AMINES ARE HIGHLY EXCITATORY STIMULI, SOME PEPTIDES AND PROTEINS ARE MODEREEERATELY EXCITATORY, WHEREAS CARBOHYDRATES, ALCOHOLS, NUCLEOSIDES, AND NUCLEOTIDES ARE IN GENERAL ONLY SLIGHTLY EXCITATORY (DERBY AND ATEMA 1982A). BY SINGLE-UNIT EXRTRACELLULAR RECORDING TECHNIQUES, THE SPECIFICTY OF SINGLE PRIMARY CHEMORECEPTORS CELLS IS DSESCRIBED HERE IN DETAIL.

DODGE, RICHARD E., AND ALINA SZMANT-FROELICH. IN PRESS. EFFECTS OF DRILLING FLUIDS ON REEF CORALS: A REVIEW. IN: WASTES IN THE OCEAN, VOLUME IV: ENERGY WASTES IN THE OCEAN. I.W. DUEDALL, EDITOR, JOHN WILEY & SONS, INC., NEW YORK, NY. (ERL,GB 480).

THIS CHAPTER REVIEWS RESEARCH ON THE EFFECTS OF DRILLING MUD ON CORAL REEF COMMUNITIES, CONCENTRATION ON THE MAJOR REEF FAUNA: THE REEF-BUILDING OR HERMATYPIC CORALS. DRILLING MUD IS AN EFFLUENT INTRODUCED TO THE MARINE ENVIRONMENT IN LARGE QUANTITES DURING A TYPICAL OFFSHORE DRILLING OPERATION. CONCERN OVER ITS POSSIBLE DETRIMENTAL EFFECTS, WHEN DRILLING ACTIVITIES ARE NEAR CORAL REEFS, HAS BEEN THE IMPETUS FOR THE WORK TO BE DISCUSSED. THE TOPIC IS OF RECENT ORIGIN; UNTIL 1977, THERE WERE NO LITERATURE REPORTS OF DRILLING MUD - CORAL STUDIES.

DODGE, R.E. 1982. EFFECTS OF DRILLING MUD ON THE REEF-BUILDING CORAL MONTASTREA ANNULARIS. MAR. BIOL. 71(2):141-147. (ERL,GB 473*). AVAIL. FROM NTIS, SPRINGFIELD, VA: PB83-182956.

THE SKELETAL EXTENSION AND CORALLITE SHAPE OF INDIVIDUALS OF THE CARIBBEAN AND ATLANTIC REEF-BUILDING CORAL MONTASTREA ANNULARIS (ELLIS AND SOLANDER) WERE MEASURED AFTER MORE THAN SIX WEEK'S CONTINUOUS FLOW-THROUGH EXPOSURE IN LABORATORY AQUARIA TO TREATMENTS OF 0, 1, 10 AND 100-PPM (UL 1E-1) DRILLING MUD. LINEAR INCREASE OF THE SKELETON (EXTENSION RATE) AND FOSSA LENGTH WERE SIGNIFICANTLY DEPRESSED IN THE 100-PPM TREATMENT. CHRONIC EXPOSURE TO 100-PPM DRILLING MUD IMPAIRS CORAL SKELETAL GROWTH RATE AND POSSIBLY INTERFERES WITH SEDIMENT REJECTION CAPABILITY BY LOWERING CALICAL RELIEF.

DODGE, RICHARD E. 1982. GROWTH CHARACTERISTICS OF REEF-BUILDING CORALS WITHIN AND EXTERNAL TO A NAVAL ORDINANCE RANGE: VIEQUES, PUERTO RICO. IN: REEF AND MAN: PROCEEDINGS OF THE FOURTH INTERNATIONAL CORAL REEF SYMPOSIUM, MANILA, PHILIPPINES, 18-22, MAY, 1981. EDGARDO D. GOMEZ, ET AL., EDITOR, MARINE SCIENCE CENTER, UNIVERSITY OF THE PHILIPPINES, QUEZON CITY, PHILIPPINES. PP. 241-248. (ERL,GB X424).

THE SKELETAL GROWTH OF REEF-BUILDING CORALS IS KNOWN TO BE SENSITIVE TO THE ENVIRONMENT. IN PARTICULAR, HIGH LEVELS OF SEDIMENTAION AND TURBIDITY LEAD TO DECREASED GROWTH RATE, SUPPRESSED GROWTH VARIATION, AND ULTIMATELY, CORAL DEATH BECAUSE OF REDUCED ILLUMINATION NECESSARY TO ZOOXANTHELLAE AND/OR INCREASED ENERGY EXPENDITURE BY THE CORAL ANIMAL TO REMOVE IMPACTED SEDIMENTS. TO ASSESS THE EFFECT OF NAVAL ORDINANCE RANGE USAGE AT VIEQUES, PUERTO RICO, SPECIMENS OF MONTASTREA ANNUALRIS WERE COLLECTED FROM REEFS ADJACENT TO AND REMOVED FROM THE RANGE AREA. GROWTH WAS MEASURED FROM ANNUAL INCREASMENTS REVEALED BY X-RADIOGRAPHY OF MEDIAL SLABS OF THE CORAL SKELETONS. MEAN GROWTH RATES AND GROWTH VARIANCES WERE CALCULATED FOR EACH STATION OR STATION GROUPING OVER THE COMMON TIME PERIOD 1970-1977. STATISTICAL COMPARISON OF THE GROWTH DATA REVEALS A GENERAL SIMILARITY BETWEEN RANGE AND CONTROL STATIONS. THIS EVIDENCE COUPLED WITH QUANTITATIVE CORAL ABUNDANCE AND DIVERSTIY DATA OF OTHERS INDICATE A LACK OF ANOMALOUS AND ADVERSE SEDIMENTATION/TURBIDITY CONDITIONS AFFECTING CORALS ON REEFS NEARBY THE RANGE AREA. CHRONOLGIES OF CORAL BAND WIDTHS COMPARED TO HISTORICAL RECORDED ENVIRONMENTAL DATA INDICATES THAT A MAJOR NATURAL PARAMETER WHICH CONTROLS CORAL GROWTH IN VIEQUES IS ANNUAL WATER TEMPERATURE VARIATIONS.

DODGE, RICHARD E., AND JUDITH C. LANG. 1983. ENVIRONMENTAL CORRELATES OF HERMATYPIC CORAL (MONTASTREA ANNULARIS) GROWTH ON THE EAST FLOWER GARDENS BANK, NORTHWEST GULF OF MEXICO. LIMNOL. OCEANOGR. 28(2):228-240. (ERL,GB X378*).

TIME SERIES OF ANNUAL LINEAR GROWTH INCREASMENTS FROM 12 MONTASTREA ANNULARIS (E. AND S.) HERMATYPIC CORALS COLLECTED AT THE EAST FLOWER GARDENS BANK REEF IN THE NORTHWESTERN GULF OF MEXICO HAVE A COMMON PATTERN. THIS IS BEST EXPRESSED IN AN INDEX MASTER CHRONOLOGY (AVERAGE BY YEAR OF THE ANNUAL PERCENTAGE DEVIATIONS FROM THE MEAN OF EACH CORAL). COMPARISONS WITH TIME SERIES OF ENVIRONMENTAL DATA INDICATE THAT CORAL EXTENSION RATES VARY POSITIVELY WITH SEASONAL (FEBRUARY THROUGH MAY - 4 MONTHS) SURFACE WATER TEMPERATURE AND NEGATIVELY WITH ANNUAL DISCHARGE OF THE ATCHAFALAYA RIVER. WE PROPOSE THE SECULAR VARIATIONS OF WATER TEMPERATURE AND OTHER PARAMETERS ARE THE MAJOR LONG-TERM CONTROLS OF CORAL GROWTH IN THE AREA. OUR DATA DO NOT SUPPORT THE VIEW THAT SINKING OF THE FLOWER GARDENS REEF, CAUSED BY CATASTROPHIC COLLAPSE OF THE UNDERLYING SUBSTRATE, HAS BEEN A PRIME INFLUENCE ON THE CORALS.

DOUGHTIE, DANIEL G., AND K. RANGA RAO. 1978. ULTRASTRUCTURAL CHANGES INDUCED BY SODIUM PENTACHLOROPHENATE IN THE GRASS SHRIMP, PALAEMONETES PUGIO, IN RELATION TO THE MOLT CYCLE. IN: PENTACHLOROPHENOL: CHEMISTRY, PHARMACOLOGY, AND ENVIRONMENTAL TOXICOLOGY. K. RANGA RAO, EDITOR, PLENUM PRESS, NEW YORK, NY. PP. 213-250. (ERL,GB X060*).

> INTERMOLT (STAGE C) GRASS SHRIMP WERE EXPOSED TO 1.0 PPM NA-PCP FOR THE DURATION OF A MOLT CYCLE. GILLS, HEPATOPANCREAS, MIDGUT (PORTION OF THE DIGESTIVE TRACT SURROUNDED BY HEPATOPANCREAS) AND HINDGUT (PORTION OF THE DIGESTIVE TRACT IN THE ABDOMEN) FROM CONTROL AND EXPERIMENTAL SHRIMP AT KNOWN STAGES OF THE MOLT CYCLE WERE EXAMINED AT THE ULTRASTRUCTURAL LEVEL. ALTHOUGH SIGNS OF PATHOLOGY WERE EVIDENT IN LATE PROECDYSIAL SHRIMP, EXTENSIVE PATHOLOGICAL CHANGES WERE NOT OBSERVED UNTIL AFTER ECDYSIS. THE EXTENT OF PATHOLOGICAL CHANGES VARIED WITH THE TISSUE EXAMINED AND THE INTERVAL BETWEEN ECDYSIS AND THE TIME OF FIXATION FOR ELECTRON MICROSCOPY. THE FOLLOWING ULTRASTRUCTURAL CHANGES WERE SEEN IN THE GILL EPITHELIUM OF SHRIMP EXPOSED TO NA-PCP: FORMATION OF FLUID FILLED INVAGINATION OF THE INTERMICROVILLAR APICAL MEMBRANE, INCREASE IN LYSOSOMAL ACTIVITY AND EVENTUAL CYTOPLASMIC AND NUCLEAR DEGENERATION. THE PODOCYTES IN THE GILL AXIS, THE GRANULAR SECRETORY CELLS AND THE TEGUMENTAL GLAND CELLS ALSO EXHIBITED MITOCHONDRIAL SWELLING, NUCLEAR PYKNOSIS AND EVENTUAL CYTOPLASMIC DEGENERATION. THE CELLS LINING THE LUMEN OF THE MIDGUT AND HINDGUT OF SHRIMP EXPOSED TO NA-PCP EXHIBITED SWELLING OF THE APICAL MEMBRANE OFTEN ACCOMPANIED BY RUPTURE, LOSS OF MICROVILLI FROM APICAL FOCI AND INCREASED LYSOSOMAL ACTIVITY. PATHOLOGICAL CHANGES NOTED IN THE HEPATOPANCREATIC CELLS OF THE EXPERIMENTAL SHRIMP WERE: HIGH AMPLITUDE SWELLING OF MITOCHONDRIA INCLUDING VESICULATION OF CRISTAE, PRESENCE OF MYELIN BODIES WITHIN MITOCHONDRIA AND ROUGH ENDOPLASMIC RETICULUM, INCREASE OF AUTOPHAGIC ACTIVITY AND LOSS OF MICROVILLI.

DOUGHTIE, D.G., AND K. RANGA RAO. 1979. COMPARATIVE ULTRASTRUCTURE OF THREE TYPES OF TEGUMENTAL GLANDS IN THE GILLS OF THE GRASS SHRIMP, PALAEMONETES PUGIO (ABSTRACT). AM. ZOOL. 19(3):890. (ERL,GB X236*).

> A UNICELLULAR GLAND AND TWO TYPES OF MULTICELLULAR ROSETTE TEGUMENTAL GLANDS OCCUR IN THE GILL AXIS OF PALAEMONETES. IN ONE TYPE OF ROSETTE GLAND, THE SECRETORY CELLS HAVE A DEEPLY INFOLDED BASAL PLASMALEMMA AND NUMEROUS MITOCHONDRIA; THIS GLAND APPEARS TO BE INNERVATED. IN THE OTHER TYPE OF ROSETTE GLAND, THE SECRETORY CELLS HAVE A RELATIVELY SMOOTH BASAL PLASMALEMMA AND FEW MITOCHONDRIA; BUT THEY POSSESS EXTENSIVE RER AND MANY GOLGI BODIES. ACCESSORY CELLS, THE HILLOCK AND CANAL CELLS, OCCUR IN ASSOCIATION WITH BOTH TYPES OF ROSETTE GLANDS. THE ROSETTE GLANDS AND THE UNICELLULAR GLANDS ARE EXOCRINE, THE SECRETIONS BEING TRANSPORTED THROUGH CUTICULARIZED DUCTULES. THE HILLOCK AND CANAL CELLS FORM THE FIBROUS BASAL REGION AND EPICUTICULAR APICAL REGION OF THE DUCTULE, RESPECTIVELY. TRANSITORY CILIARY STRUCTURES ASSOCIATED WITH DUCTULE REFORMATION ARE SEEN IN THE UNICELLULAR GLANDS AND THE DEVELOPING ROSETTE GLANDS, BUT NOT IN THE FULLY DEVELOPED ROSETTE GLANDS.

DOUGHTIE, DANIEL G., AND K. RANGA RAO. 1979. ULTRASTRUCTURE OF AN EXOCRINE DERMAL GLAND IN THE GILLS OF THE GRASS SHRIMP, PALAEMONETES PUGIO: OCCURRENCE OF TRANSITORY CILIARY AXONEMES ASSOCIATED WITH THE SLOUGHING AND REFORMATION OF THE DUCTULE. J. MORPHOL. 161(3):281-307. (ERL,GB X150).

> EXOCRINE DERMAL GLANDS, COMPARABLE TO THE CLASS 3 GLANDULAR UNITS OF INSECTS, ARE FOUND IN THE GILLS OF THE GRASS SHRIMP, PALAEMONETES PUGIO. THE DERMAL GLANDS ARE COMPOSED OF THREE CELLS: SECRETORY CELL, HILLOCK CELL AND CANAL CELL. ORIGINATING AS A COMPLEX INVAGINATION OF THE APICAL CYTOPLASM OF THE GRANULAR SECRETORY CELL, A DUCT ASCENDS THROUGH THE HILLOCK AND CANAL CELLS TO THE CUTICULAR SURFACE. THE DUCT IS DIVISABLE INTO FOUR REGIONS: THE SECRETORY APPARATUS IN THE GRANULAR SECRETORY CELL, THE LOCULAR COMPLEX, THE HILLOCK REGION WITHIN THE HILLOCK CELL AND THE CANAL WITHIN THE CANAL CELL. A TUBULAR DUCTULE IS CONTAINED WITHIN THE LATTER TWO REGIONS. AS THE DUCTULE ASCENDS TO THE CUTICULAR SURFACE, ITS CONSTITUTION GRADUALLY CHANGES FROM ONE OF A FIBROUS MATERIAL TO ONE WHICH POSSESSES LAYERS OF EPICUTICLE. DURING THE PROECDYSIAL PERIOD, THE DUCTULE IS EXTRUDED INTO THE ECDYSIAL SPACE AND THIS IS FOLLOWED BY THE SECRETION OF A NEW DUCTULE. CHARACTERIZED ONLY BY A BASAL BODY AND ROOTLETS THROUGHOUT MOST OF THE INTERMOLT CYCLE, THE CILIARY ORGANELLES GIVE RISE TO TEMPORARY AXONEMIC PROCESSES WHICH ASCEND THROUGH THE DUCTULE TOWARD THE ECDYSIAL SPACE AT THE ONSET OF PROECDYSIS. SUSEQUENTLY, THE OLD DUCTULE IS SLOUGHED OFF AND A NEW DUCTULE IS REFORMED AROUND THE CILIARY AXONEMES. FOLLOWING THIS REFORMATION, THE CILIARY AXENEMES DEGENERATE. THE FUNCTION OF CYTOPLASMIC PROCESSES, DERIVED FROM THE APICAL CYTOPLASM OF THE SECRETORY CELL, IS ALSO DISCUSSED.

DOUGHTIE, D.G., AND K.R. RAO. 1981. CILIARY STRUCTURES IN THE BRANCHIAL UNICELLULAR GLANDS OF THE GRASS SHRIMP, PALAEMONETES PUGIO. EXPERIENTIA (BASEL). 37(5):502-503. (ERL,GB X423).

> A UNICELLULAR EXOCRINE GLAND POSSESSING AN EPICUTICLAR DUCTULE OCCURS IN GRASS SHRIMP GILLS. THIS GLAND DISPLAYS ULTRASTRUCTURAL CHANGES IN RELATION TO THE MOLT CYCLE. THESE CHANGES INCLUDE AN INCREASE IN THE QUANTITY OF SECRETORY GRANULES DURING LATE PREMOLT, AND THE DEVELOPMENT OF CILIARY AXONEMES IN RELATION TO DUCTULE FORMATION.

DOUGHTIE, DANIEL G., AND K. RANGA RAO. 1981. SYNCYTIAL NATURE AND PHAGOCYTIC ACTIVITY OF THE BRANCHIAL PODOCYTES IN THE GRASS SHRIMP, PALAEMONETES PUGIO. TISSUE & CELL. 13(1):93-104. (ERL,GB X234*).

THE MORPHOLOGY OF THE BRANCHIAL PODOCYTES IN THE GRASS SHRIMP, PALAEMONETES PUGIO, WAS INVESTIGATED IN RELATION TO THE MOLT CYCLE. THE PODOCYTES ARE LOCATED IN THE EFFERENT HEMOLYMPH CHANNELS IN THE GILL AXIS, AND POSSESS A SPECIALIZED PLASMALEMMA CONSISTING OF INTERDIGITATION PEDICEL PROCESSES WHICH ARE BRIDGED BY THIN DIAPHRAGMS. THE TOPOGRAPHY OF THE PLASMALEMMAL SURFACE SUGGESTS THAT THESE CELLS, LIKE SIMILAR CELLS IN OTHER ARTHROPODS, FUNCTION IN THE ULTRAFILTRATION OF MICRO- AND MACRO- MOLECULAR SUBSTANCES FROM THE HEMOLYMPH. ADDITIONALLY, THE BRANCHIAL PODOCYTES EXHIBIT PHAGOCYTIC ACTIVITY. THIS ACTIVITY, THOUGH EVIDENT DURING THE PREMOLT PERIOD, IS MOST PROMINENT DURING THE EARLY POSTMOLT PERIOD. AMONG THE CELL TYPES SUBJECTED TO PHAGOCYTOSIS BY PODOCYTES ARE THE SECRETORY CELLS OF THE TRICELLULAR AND ROSETTE-TYPE DERMAL GLANDS AND THE EPITHELIAL CELLS OF THE GILL AXIS. DURING THE LATE PREMOLT AND EARLY POSTMOLT PERIODS, THE PODOCYTES OFTEN APPEAR AS SYNCYTIA, CONTAINING AS MANY AS FOUR NUCLEI. THE EXACT INTERRELATIONSHIPS BETWEEN PHAGOCYTOSIS AND SYNCYTIAL FORMATION REMAIN TO BE ASCERTAINED. THESE ASPECTS AND THE POSSIBLE AMBULATORY ABILITIES OF THE BRANCHIAL PODOCYTES ARE DISCUSSED.

DOUGHTIE, DANIEL G., AND K. RANGA RAO. 1982. ROSETTE GLANDS IN THE GILLS OF THE GRASS SHRIMP, PALAEMONETES PUGIO. I. COMPARATIVE MORPHOLOGY, CYCLICAL ACTIVITY, AND INNERVATION. J. MORPHOL. 171(1):41-67. (ERL,GB X238*). AVAIL. FROM NTIS, SPRINGFIELD, VA: PB82-207846.

TWO TYPES OF EXOCRINE ROSETTE GLANDS (CALLED TYPE A AND TYPE B), LOCATED IN THE GILL AXES OF THE GRASS SHRIMP, PALAEMONETES PUGIO, ARE DESCRIBED. THE TYPE A GLANDS ARE EMBEDDED WITHIN THE LONGITUDINAL MEDIAN SEPTUM OF THE GILL AXES, WHEREAS THE TYPE B GLANDS TYPICALLY PROJECT INTO THE EFFERENT HEMOLYMPH CHANNELS OF THE GILL AXES. ALTHOUGH BOTH GLANDS HAVE CERTAIN COMMON CHARACTERISTICS (I.E., A VARIABLE NUMBER OF RADIALLY ARRANGED SECRETORY CELLS, A CENTRAL INTERCALARY CELL, AND A CANAL CELL THAT FORMS THE CUTICULAR DUCTULE LEADING TO THE BRANCHIAL SURFACE), THEY DIFFER IN THE FOLLOWING RESPECTS. THE TYPE B GLAND IS INNERVATED, BUT THE TYPE A GLAND IS NOT; AXONAL PROCESSES, CONTAINING BOTH GLANDULAR (CA. 900-1300 A) AND AGRANULAR (CA. 450-640 A) VESICLES, OCCUR AT A JUNCTURE BETWEEN ADJACENT SECRETORY CELLS AND THE CENTRAL CELL OF THE TYPE B GLAND. THE SECRETORY CELLS OF TYPE A AND TYPE B GLANDS DIFFER IN THEIR SYNTHETIC POTENTIAL AND MEMBRANE SPECIALIZATIONS. THESE DIFFERENCES ARE MORE PRONOUNCED IN WELL-DEVELOPED, MATURE GLANDS, MOST FREQUENTLY ENCOUNTERED IN LARGER (24-28 MM, TOTAL LENGTH) GRASS SHRIMP, THAN IN THE UNDERDEVELOPED, IMMATURE GLANDS THAT ARE MOST ABUNDANT IN SMALLER (14-18 MM, TOTAL LENGTH) GRASS SHRIMP. THUS, IN MATURE GLANDS, THE SECRETORY CELLS OF THE TYPE A ROSETTE GLANDS ARE CHARACTERIZED BY EXTENSIVE RER, ABUNDANT GOLGI, AND NUMEROUS SECRETORY GRANULES, WHEREAS THE SECRETORY CELLS OF THE TYPE B GLAND ARE CHARACTERIZED BY EXTENSIVELY INFOLDED AND INTERDIGITATED BASAL PLASMALEMMAS AND BY THE PRESENCE OF NUMEROUS MITOCHONDRIA. IN GENERAL, BOTH TYPES OF GLANDS EXHIBIT INCREASED SECRETORY ACTIVITY SOON AFTER ECDYSIS. THE CENTRAL AND CANAL CELLS IN BOTH GLANDS SEEM TO HAVE A ROLE IN THE MODIFICATION OF THE SECRETED MATERIALS. THE POSSIBLE FUNCTIONS ASSIGNED TO THE TYPE A GLAND AND THE TYPE B GLAND INCLUDE PHENOL-OXIDASE SECRETION AND OSMOREGULATION, RESPECTIVELY.

DOUGHTIE, DANIEL G., AND K. RANGA RAO. 1982. ROSETTE GLANDS IN THE GILLS OF THE GRASS SHRIMP, PALAEMONETES PUGIO. II. PREMOLT DUCTULE REFORMATION: REPLACEMENT OF CILIARY PROCESSES BY CYTOPLASMIC PROCESSES IN RELATION TO GLAND MATURATION. J. MORPHOL. 171(1):69-77. (ERL,GB X239*).

THE EVENTS ASSOCIATED WITH PREMOLT REFORMATION OF THE CUTICULARIZED DUCTULE IN THE UNDERDEVELOPED (IMMATURE) BRANCHIAL ROSETTE GLANDS, WHICH ARE COMMON IN THE GILLS OF SMALL (14-18 MM, TOTAL LENGTH) GRASS SHRIMP, ARE DESCRIBED AND CONTRASTED WITH THE EVENTS OF DUCTULE REFORMATION IN THE FULLY DEVELOPED (MATURE) ROSETTE GLANDS MOST COMMON IN LARGER SHRIMP. IN IMMATURE ROSETTE GLANDS TWO CILIARY PROCESSES EMERGE FROM EACH OF THE COMPONENT SECRETORY CELLS AND ASCEND INTO THE BASAL LUMINAL REGION OF THE OLD DUCTULE. SUBSEQUENTLY A NEW DUCTULE IS FORMED AROUND THE OLD DUCTULE, AND THE CILIARY PROCESSES DISAPPEAR EITHER BECAUSE OF DEGENERATION OR RETRACTION. THE TRANSITORY CILIARY PROCESSES APPEAR TO PREVENT THE OLD DUCTULE. SUCH TRANSITORY CILIARY PROCESSES, HOWEVER, ARE NOT FOUND IN ASSOCIATION WITH PREMOLT DUCTULE REFORMATION IN THE MATURE ROSETTE GLANDS; IN THEIR PLACE ARE SEEN A NUMBER OF MICROVILLI-LIKE CYTOPLASMIC PROCESSES, WHICH EMANATE FROM THE APICES OF THE SECRETORY CELLS AND FROM THE CHANNELS OF THE CENTRAL CELL. THESE CYTOPLASMIC PROCESSES IN MATURE GLANDS, LIKE THE CILIARY PROCESSES IN IMMATURE GLANDS, ARE TRANSITORY AND APPEAR TO PREVENT THE COLLAPSE OF THE OLD DUCTULE. CYTOPLASMIC PROCESSES COMPARABLE TO THOSE IN MATURE GLANDS, BUT RELATIVELY FEW IN NUMBER AND ORIGINATING ONLY FORM THE SECRETORY CELLS, ARE SEEN TOGETHER WITH CILIARY PROCESSES IN SOME IMMATURE GLANDS. THE RELATIVE ABUNDANCE OF CYTOPLASMIC PROCESSES IN THE MATURE GLANDS, COUPLED WITH THE OBSERVATION THAT TRANSITORY CILIARY PROCESSES OCCUR IN IMMATURE GLANDS BUT NOT IN MATURE GLANDS, SUGGESTS THAT, DURING GLANDULAR MATURATION, TRANSITORY CILIARY PROCESSES ARE REPLACE BY TRANSITORY CYTOPLASMIC PROCESSES.

DOUGHTIE, DANIEL G., PHILIP J. CONKLIN, AND K. RANGA RAO. 1983. CUTICULAR LESIONS INDUCED IN GRASS SHRIMP EXPOSED TO HEXAVALENT CHROMIUM. J. INVERTEBR. PATHOL. 42(2):249-258. (ERL,GB X434*).

ADULT GRASS SHRIMP WERE EXPOSED TO FOUR CONCENTRATIONS (0.5, 1.0, 2.0, 4.0 PPM) OF HEXAVALENT CHROMIUM FOR 28 DAYS. AT THE END OF THE EXPOSURE PERIOD, OVER FIFTY PERCENT OF THE SURVIVING SHRIMP POSSESSED CUTICULAR LESIONS THAT HAD MANY OF THE GROSS CHARACTERISTICS OF "SHELL DISEASE". THESE LESIONS WERE USUALLY ASSOCIATED WITH ARTICULATIONS OF THE APPENDAGES AND ABDOMEN. FURTHERMORE, IT WAS FOUND THAT AT INCREASING LEVELS OF CHROMIUM EXPOSURE, THERE WAS A PROPORTIONATE INCREASE IN THE LOSS OF LIMBS SUCH THAT NEARLY 50% OF THE LIMBS WERE LOST IN GRASS SHRIMP EXPOSED TO THE HIGHEST TEST CONCENTRATION OF CHROMIUM. HISTOLOGICAL AND ULTRASTRUCTURAL EXAMINATION OF NUMEROUS LESIONS DEMONSTRATED A RANGE OF DEGENERATIVE FEATURES WITHIN THE SUBCUTICULAR EPITHELIUM THAT INCLUDED CYTOPLASMIC VACUOLIZATION, MITOCHONDRIAL SWELLING, CHROMATIN EMARGINATION AND THE PRESENCE OF UNUSUAL NUCLEAR INCLUSIONS THAT APPEAR TO INDICATE DIRECT CHROMIUM TOXICITY. ADDITIONALLY A MARKED RETARDATION IN NEW EPICUTICLE AND EXOCUTICLE FORMATION WAS OBSERVED IN VIABLE TISSUES ASSOCIATED WITH LESIONS IN LATE PREMOLT SHRIMP. IT IS PROPOSED THAT CHROMIUM INTERFERES WITH THE NORMAL FUNCTIONS OF SUBCUTICULAR EPITHELIUM, PARTICULARLY CUTICLE FORMATION, AND SUBSEQUENTLY CAUSES STRUCTURAL WEAKNESSES OR PERFORATIONS TO DEVELOP IN THE CUTICLE OF NEWLY MOLTED SHRIMP. BECAUSE OF THESE CHROMIUM-INDUCED EXOSKELETAL DEFICIENCIES, A VIADUCT FOR PATHOGENIC ORGANISMS (E.G., BACTERIA) AND DIRECT CHROMIUM INFLUX IS FORMED THAT PERPETUATES LESION DEVELOPMENT.

DOUGHTIE, DANIEL G., AND K. RANGA RAO. 1983. ULTRASTRUCTURAL AND HISTOLOGICAL STUDY OF DEGENERATIVE CHANGES IN THE ANTENNAL GLANDS, HEPATOPANCREAS, AND MIDGUT OF GRASS SHRIMP EXPOSED TO TWO DITHIOCARBAMATE BIOCIDES. J. INVERTEBR. PATHOL. 41(3):281-299. (ERL,GB X395*).

HISTOLOGICAL AND ULTRASTRUCTURAL ALTERATIONS OBSERVED IN THE ANTENNAL GLANDS, HEPATOPANCREAS, AND MIDGUT OF GRASS SHRIMP EXPOSED TO EITHER A 50% POTASSIUM DIMETHYLDITHIOCARBAMATE BIOCIDE (BUSAN-85; 5-60 PPB) FOR 14 DAYS, OR TO A DIFFERENT BIOCIDE, COMPOSED OF 15% SODIUM DIMETHYLDITHIOCARBAMATE AND 15% SODIUM ETHYLENE BIODITHIOCARBAMATE (AQUATREAT DNM-30), FOR 3-4 DAYS (60-140 PPB) AND 28-35 DAYS (40-120 PPB), WERE COMPARED AND CONTRASTED WITH THE NORMAL MORPHOLOGICAL FEATURES IN CONTROL SHRIMP. ONLY THOSE EXPERIMENTAL SHRIMP THAT EXHIBITED VARIOUS DEGREES OF BRANCHIAL ABNORMALITY WERE EXAMINED. ALTHOUGH THE ALTERATIONS IN BUSAN-EXPOSED SHRIMP WERE GENERALLY MORE PRONOUNCED, THE ANTENNAL GLANDS OF 32 OUT 36 EXPERIMENTAL SHRIMP EXHIBITED ABNORMALITIES THAT WERE MANIFESTED PRIMARILY AS INCREASED SECRETORY ACTIVITY BY THE LABYRINTH CELLS. IN DITHIOCARBAMATE-EXPOSED SHRIMP WITH "BLACK GILLS," THE LABYRINTH EPITHELIUM EXHIBITED MODERATE NUCLEAR HYPERTROPHY, APPARENT CELL SLOUGHING, INTENSE SECRETORY ACTIVITY, AND OCCASIONAL MELANIZED LESIONS; ALTERATIONS IN THE ANTENNAL GLAND COELOMOSAC INCLUDED NUCLEAR PYKNOSIS, A GENERAL DETERIORATION OF PODOCYTE ORGANIZATION, AND AN UNUSUAL INCREASE IN HEMOLYMPH DENSITY ADJACENT TO AFFECTED TISSUES. ALTHOUGH THERE WAS AN APPARENT INCREASE IN MITOTIC ACTIVITY IN THE HEPATOPANCREATIC TUBULES OF SHRIMP EXPOSED TO AQUATREAT FOR 28-35 DAYS, DEGENERATIVE CHANGES WERE MOST FREQUENT AND EXTENSIVE IN THE HEPATOPANCREAS AND MIDGUT OF DITHIOCARBAMATE-EXPOSED SHRIMP WITH "BLACK GILLS." THESE OBSERVED CHANGES INCLUDED THE DIMINUTION OF THE BASAL MIDGUT AND HEPATOPANCREATIC FIXED PHAGOCYTES, DEVELOPMENT OF MITOCHONDRIAL INCLUSIONS AND MEGAMITOCHONDRIA, LOSS OF CYTOPLASMIC DENSITY, HEPATOPANCREATIC NUCLEAR PYKNOSIS, AND IRREVERSIBLE DEGENERATION OF HEPATOPANCREATIC TUBLUE APICES. THIS STUDY SUGGESTS THAT SOME OF THE OBSERVED ABNORMAL/PATHOLOGICAL CHANGES ARE THE INDIRECT CONSEQUENCE OF BRANCHIAL DEGENERATION. A NUMBER OF POSSIBLE DEFENSIVE REACTIONS TO DITHIOCARBAMATE POISONING, INCLUDING HETEROSTASIS, PHAGOCYTOSIS, ENCAPSULATION, AND THE POSSIBLE PARTICIPATION OF RESERVE INCLUSION CELLS ARE PROPOSED.

DOUGHTIE, DANIEL G., AND K. RANGA RAO. 1983. ULTRASTRUCTURAL AND HISTOLOGICAL STUDY OF DEGENERATIVE CHANGES LEADING TO BLACK GILLS IN GRASS SHRIMP EXPOSED TO A DITHIOCARBAMATE BIOCIDE. J. INVERTEBR. PATHOL. 41(1):33-50. (ERL,GB X384*).

PATHOLOGIC "MILKY" AND BROWN-BLACK GILLS OF GRASS SHRIMP, PALAEMONETES PUGIO, EXPOSED TO LOW LEVELS (5 TO 60 PPB) OF A 50% POTASSIUM-DIMETHYLDITHIOCARBAMATE BIOCIDE (BUSAN-85) FOR 14 DAYS WERE STUDIED USING LIGHT AND ELECTRON MICROSCOPY. IN SHRIMP EXPOSED TO 5 PPB BUSAN-85, A GRADATION OF DEGENERATIVE CHANGES COULD BE ASCERTAINED BOTH WITHIN THE GILLS OF INDIVIDUAL SHRIMP AND AMONG THE GILLS OF DIFFERENT SHRIMP. PRIMARY DEGENERATIVE CHANGES, FIRST EVIDENT IN THE APICAL EPITHELIUM OF THE LAMELLAR PLATES, INCLUDED: SWOLLEN MITOCHONDRIA, DILATED ROUGH ENDOPLASMIC RETICULUM, THE APPEARANCE OF A DENSE GRAINY MATERIAL WITHIN THE SUBCUTICULAR SPACES AND OF PARACRYSTALLINE ELEMENTS WITHIN THE EPITHELIAL CYTOPLASM, THE FORMATION OF AUTOPHAGOSOMES, AND A LOSS OF MEMBRANE CONTINUITY. GRANULAR HEMOCYTES MIGRATED INTO THE SUBCULTULAR SPACES AND APPEARED TO PHAGOCYTOSE THE GRAINY MATERIAL, WHILE OTHER HEMOCYTES PHAGOCYTOSED AND ENCAPSULATED THE PATHOLOGICAL EPITHELIUM. LATER, THE LAMELLAR TIPS BECAME CONGESTED WITH NUMEROUS INTERDIGITATING HEMOCYTES WHICH FORMED A "PLUG". A NEW EPITHELIUM, DERIVED PARTLY FROM MITOSIS OF BASAL LAMELLAR TISSUES, DEVELOPED SUBJACENT TO THE PLUG AND CONTRIBUTED TO THE FORMAION OF AN ABNORMAL AND SOMETIMES PERFORATED CUTICLE DURING PREMOLT. AT ECDYSIS, THE HEMOCYTE PLUGS IN THE APICAL REGION OF THE LAMELLA WERE SLOUGHED RESULTING IN MARKEDLY TRUNCATED AND SWOLLEN LAMELLAE. THIS PROCESS OF PATHOLOGICAL LAMELLAR REDUCTION APPEARS TO BE AN IMPORTANT DEFENSE MECHANISM IN RESPONSE TO BRANCHIAL TRAUMA CAUSED BY EXPOSURE TO ENVIRONMENTAL CONTAMINANTS.

DOUGHTIE, DANIEL G., AND K. RANGA RAO. 1984. HISTOPATHOLOGICAL AND ULTRASTRUCTURAL CHANGES IN THE ANTENNAL GLAND, MIDGUT, HEPATOPANCREAS, AND GILL OF GRASS SHRIMP FOLLOWING EXPOSURE TO HEXAVALENT CHROMIUM. J. INVERTEBR. PATHOL. 43(1):89-108. (ERL,GB X400*).

GRASS SHRIMP, PALAEMONETES PUGIO, WERE EXPOSED FOR ONE MONTH TO SUBACUTE CONCENTRATIONS OF HEXAVALENT CHROMIUM (0.5, 1.0, 2.0, 4.0 PPM) AFTER WHICH THE GILLS, MIDGUT, HEPATOPANCREAS, AND ANTENNAL GLANDS WERE EXAMINED FOR HISTOPATHOLOGICAL AND ULTRASTRUCTURAL CHANGES. PATHOLOGICAL CHANGES WERE GREATEST IN THE ANTENNAL GLANDS, FOLLOWED BY HEPATOPANCREAS, GILLS, AND MIDGUT. SEVERE CHANGES OCCURRED IN SOME SHRIMP, EVEN AT 0.5 PPM CHROMIUM. CELLS OF ALL TISSUES FREQUENTLY HAD BOTH SWOLLEN MITOCHONDRIA AND ROUGH ENDOPLASMIC ETICULUM. SMALL, SPHERICAL OR RING-LIKE INTRANUCLEAR INCLUSIONS, POSSIBLE INDICATIVE OF CELLULAR HYPERACTIVITY OR MANIFESTIONS OF CHROMIUM AND/OR PROTEIN COMPLEXES, WERE MOST PREVALENT IN THE HEPATOPANCREAS AND ANTENNAL GLANDS BUT ALSO OCCURRED IN THE MIDGUT AND GILLS. OTHER MAJOR DEGENERATIVE CHANGES IN THE ANTENNAL GLANDS WERE RESTRICTED TO THE LABYRINTH AND INCLUDED DIMINUTION OF BASAL PLASMALEMMAL INFOLDINGS AND CYTOPLASMIC DENSITY, NUCLEAR HYPERTROPHY FOLLOWED BY WIDESPREAD NUCLEAR PYKNOSIS AND EPITHELIAL DESQUAMATION. IN SEVERELY ALTERED HEPATOPANCREAS HYPERTROPHY WAS INDICATED FOR THE BASAL LAMINAE, NUCLEI, POSSIBLE FOR THE NUCLEOLI. THERE WAS AN APPARENT REDUCTION IN MITOTIC EVENTS AND MANY OBSERVED MITOTIC NUCLEI WERE ABNORMAL. ABNORMAL MIDGUT HYPERTROPHY WAS PRESENT IN ONLY EIGHT OF TWENTY EXAMINED SHRIMP, EXPOSED TO 0.5 AND 1.0 PPM CHROMIUM. FURTHER, THE GILLS OF ONLY 10 OF THE 40 EXAMINED CHROMIUM-EXPOSED SHRIMP POSSESSED ABNORMAL FEATURES DETECTABLE WITH LIGHT MICROSCOPY. ULTRASTRUCTURAL ANALYSIS OF THE LATTER INDICATED AN INCREASE IN LYSOSOMES AND A DECREASE IN CYTOPLASMIC DENSITY. IN ADDITION, THERE WAS A PRONOUNCED DIMINUTION IN THE DEGREE OF LAMELLAR, SUBCUTICULAR PLASMALEMMAL INFOLDING. THIS LATTER FEATURE IS POSTULATED TO BE A MECHANISM FOR THE REGULATION OF CHROMIUM INFLUX. POSSIBLE EXPLANATIONS FOR MOST OBSERVED ALTERATIONS IN THE ABOVE TISSUES ARE PROPOSED.

DUKE, THOMAS W. IN PRESS. POTENTIAL IMPACT OF DRILLING FLUIDS ON ESTUARINE PRODUCTIVITY. IN: PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON THE UTILIZATION OF COASTAL ECOSYSTEMS: PLANNING, POLLUTION, AND PRODUCTIVITY, NOV. 22-27, 1982, RIO GRANDE, BRAZIL. (ERL,GB 449).

THIS PAPER DISCUSSES THE POTENTIAL EFFECTS OF DRILLING FLUIDS ON SEMI-ENCLOSED BODIES OF WATER SUCH AS ESTUARIES. DRILLING FLUIDS HAVE BEEN DISCHARGED INTO OUTER CONTINENTAL SHELF WATERS FOR MANY YEARS BUT THERE IS SOME CONCERN OF POTENTIAL ECOLOGICAL IMPACT WHEN DRILLING FLUID ARE DISCHARGED NEAR CORAL REEFS OR IN BAYS AND ESTUARIES. THE CONCERN IS BASED ON POTENTIAL ADVERSE EFFECTS OF THE FLUIDS TO CORALS, SHELLFISH, FISH, GRASS BEDS AND GENERAL PRODUCTIVITY. POTENTIAL EFFECTS CAN BE EVALUATED THROUGH A HAZARD ASSESSMENT PROCESS THAT INVOLVES EFFECTS AND EXPOSURE MEASUREMENTS. A SUGGESTED HAZARD ASSESSMENT INVOLVING THE ADAPTIVE ENVIRONMENTAL ASSESSMENT APPROACH (AEA) IS PRESENTED. THE COMPONENTS OF THE AEA APPROACH ARE DESCRIBED AND EVALUATED. IN DEVELOPING THE HAZARD ASSESSMENT, A REVIEW IS MADE OF EXISTING EFFECTS DATA. A PRESENTATION IS MADE OF ISSUES OF CONCERN SUCH AS RESUSPENSION OF DRILLING FLUIDS IN SHALLOW, WIND-DRIVEN ESTUARIES, RESTRICTION OF LIGHT PENETRATION TO PRIMARY PRODUCERS BY SUSPENDED SEDIMENTS, CHANGES IN BENTHIC COMMUNITIES AND THEIR SUBSTRATES, AND DIRECT TOXICITY OF THE FLUIDS TO ORGANISMS.

DUKE, THOMAS W. 1982. SUMMARY OF EPA DRILLING FLUID RESEARCH ACTIVITIES. IN: PROCEEDINGS: THIRD ANNUAL GULF OF MEXICO INFORMATION TRANSFER MEETING, AUGUST 24-26, 1982, NEW ORLEANS, LA. U.S. DEPARTMENT OF THE INTERIOR MINERALS MANAGMENT SERVICE, NEW ORLEANS, LA. PP. 85-89. (ERL,GB 461*).

> DRILLING-FLUID RELATED RESEARCH AT THE U.S. EPA ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, IS SUMMARIZED. THE PROGRAM IS CONDUCTED PRIMARILY THROUGH CONTRACTS, GRANTS, AND SOME INHOUSE PROJECTS DESIGNED TO ASSESS THE POTENTIAL HAZARD TO THE MARINE ENVIRONMENT FROM FLUIDS DISCHARGED IN OFFSHORE OIL AND GAS DRILLING AND EXPLORATIONS.

DUKE, T.W., P.R. PARRISH, R.M. MONTGOMERY, S.D. MACAULEY, J.M. MACAULEY, AND G.M. CRIPE. 1984. ACUTE TOXICITY OF EIGHT LABORATORY-PREPARED GENERIC DRILLING FLUIDS TO MYSIDS (MYSIDOPSIS BAHIA). EPA-600/3-84-067, U.S ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 11P.

> ACUTE TOXICITY TESTS WERE CONDUCTED DURING AUGUST-SEPTEMBER 1983 WITH EIGHT LABORATORY-PREPARED GENERIC DRILLING FLUIDS (ALSO CALLED MUDS) AND MYSIDS (MYSIDOPSIS BAHIA) AT THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FLORIDA. TWO OF THE DRILLING FLUIDS WERE TESTED AT THE ENVIRONMENTAL RESEARCH LABORATORY, NARRAGANSETT, RHODE ISLAND, TO CONFIRM THE VALIDITY OF THE TESTS CONDUCTED AT GULF BREEZE. THE TEST MATERIAL WAS THE SUSPENDED PARTICULATE PHASE (SPP) OF EACH DRILLING FLUID. THE SPP WAS PREPARED BY MIXING VOLUMETRICALLY 1 PART DRILLING FLUID WITH 9 PARTS SEAWATER AND ALLOWING THE RESULTING SLURRY TO SETTLE FOR ONE HOUR. THE MATERIAL THAT REMAINED IN SUSPENSION WAS THE SPP. TOXICITY OF THE SPP OF THE DRILLING FLUIDS RANGED FROM A 96-HOUR LC50 (THE CONCENTRATION LETHAL TO 50% OF THE TEST ANIMALS AFTER 96 HOURS OF EXPOSURE) OF 2.7% FOR A KC1 POLYMER MUD TO 65.4% FOR A LIGHTLY TREATED LIGNOSULFONATE MUD. NO MEDIAN EFFECT (50% MORTALITY) WAS OBSERVED IN THEREE DRILLING FLUIDS -- A NON-DISPERSED MUD, A SPUD MUD, AND A SEAWATER-FRESHWATER GEL MUD.

ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 1984. INDEX AND ABSTRACTS TO PUBLICATIONS: THE EPA DRILLING FLUID HAZARD ASSESSMENT RESEARCH PROGRAM. U.S. ENVIRONMENTAL PROTECTION AGENCY. ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 94P. (ERL,GB SR-112).

> THIS VOLUME SUMMARIES RESULTS OF AN ONGOING RESEARCH PROGRAM. FROM 1976 TO THE PRESENT TIME, ERLGB CONDUCTED A RESEARCH PROGRAM TO EVALUATE THE POTENTIAL IMPACT OF DRILLING FLUIDS ON THE MARINE ENVIRONMENT. THE EXTRAMURAL PORTION OF THIS STUDY IS ESSENTIALLY COMPLETE; HOWEVER, THE IN-HOUSE REPORT IS CONTINUING. THE EFFORT WAS A COMPOSITE OF IN-HOUSE AND EXTRAMURAL ACTIVITIES, ADAPTIVE ENVIRONMENTAL ASSESSMENTS (AEA) AND A FINAL HAZARD ASSESSMENT EFFORT (IN AGENCY REVIEW). DR. NORMAN RICHARDS DIRECTED THE PROGRAM FROM 1976 TO 1981 WHEN DR. T. W. DUKE BECAME PROJECT LEADER. OVER THAT TIME PERIOD 100 REPORTS, PUBLICATIONS AND JOURNAL ARTICLES IN THE PEER-REVIEWED LITERATURE HAVE BEEN PRODUCED. THIS PUBLICATION LISTS THE TITLE, JOURNAL OR PLACE OF PUBLICATION AND, (WHEN AVAILABLE), AN ABSTRACT OF THE PUBLICATION CONTENT. ADDITIONALLY, AN AUTHOR INDEX AND A KEY WORD INDEX ARE PROVIDED.

FARR, JAMES A. 1978. ORIENTATION AND SOCIAL BEHAVIOR IN THE SUPRALITTORAL ISOPOD LIGIA EXOTICA (CRUSTACEA: ONISCOIDEA). BULL. MAR. SCI. 28(4):659-666. (ERL,GB X071*).

LIGIA EXOTICA IS AGGREGATIVE, TENDING TO SEEK OUT CONSPECIFICS. IT IS HYPOTHESIZED THAT LIGIA MUST SEEK NEW SHELTERS REPEATEDLY WITH CHANGING TIDES BECAUSE OF THEIR RESTRICTED WATER REQUIREMENTS, AND THAT ATTRACTION TO CONSPECIFICS ALREADY IN A SUITABLE HABITAT IS AN ADDITIONAL ORIENTATIONAL MECHANISM TO THOSE EXTERNAL ENVIRONMENTAL FACTORS INFLUENCING MICROHABITAT SELECTION. EXPERIMENTS ON OBJECT ORIENTATION DEMONSTRATED A STRONG TENDENCY TO MOVE TOWARD CONTRASTING LANDMARKS, THE RESULT BEING OCCUPATION OF ROCKY AREAS ON THE SHORELINE. BRIEF DESCRIPTIONS OF SEXUAL AND AGONISTIC BEHAVIOR ARE INCLUDED.

FAZIO, STEVEN D., WILLIAM R. MAYBERRY, AND DAVID C. WHITE. 1979. MURAMIC ACID ASSAY IN SEDIMENTS. APPL. ENVIRON. MICROBIOL. 38(2):349-350. (ERL,GB X073*).

AN IMPROVED CHROMATOGRAPHIC ASSAY FOR MURAMIC ACID WHICH IS SUFFICIENTLY SENSITIVE FOR MARINE SANDY SEDIMENTS IS DESCRIBED; IT INVOLVES ACID HYDROLYSIS, THIN-LAYER CHROMATOGRAPHY, AND GAS-LIQUID CHROMATOGRAPHY.

FEDERLE, THOMAS W., AND DAVID C. WHITE. 1982. PRESERVATION OF ESTUARINE SEDIMENTS FOR LIPID ANALYSIS OF BIOMASS COMMUNITY STRUCTURE OF MICROBIOTA. APPL. ENVIRON. MICROBIOL. 44(5):1166-1169. (ERL,GB X381).

VARIOUS METHODS WERE TESTED FOR PRESERVING ESTUARINE SEDIMENTS IN THE FIELD BEFORE BIOCHEMICAL ANALYSIS OF THE MICROBIOTA. TOTAL MICROBIAL BIOMASS WAS DETERMINED AS LIPID PHOSPHATE (LP), AND THE FATTY ACIDS OF THE MICROBIAL LIPID WERE USED AS INDICATORS OF COMMUNITY STRUCTURE. CONTROL SAMPLES WERE SIEVED TO REMOVE MACROINVERTEBRATES AND PLANT MATERIALS AND WERE EXTRACTED IMMEDIATELY IN THE FIELD. OTHER SAMPLES WERE PRESERVED BOTH BEFORE AND AFTER SIEVING AND STORED FOR 5 DAYS BEFORE ANALYSIS. FREEZING RESULTED IN A 50% DECLINE IN LP AND SIGNIFICANT DECREASES IN MANY FATTY ACIDS. REFRIGERATION RESULTED IN A 19% DECREASE IN LP BUT NO CHANGE IN THE FATTY ACIDS. SAMPLES PRESERVED WITH FORMALIN BEFORE SIEVING EXHIBITED NO SIGNIFICANT CHANGE IN LP BUT SUBSTANTIAL INCREASES IN MANY FATTY ACIDS, WHICH WERE PROBABLY DERIVED FROM THE MACROINVERTEBRATES. SIEVED SAMPLES PRESERVED WITH FORMALIN SHOWED A 17 TO 18% DECLINE IN LP BUT NO CHANGE IN THE FATTY ACIDS. IDEALLY, SAMPLES SHOULD BE SIEVED AND EXTRACTED IMMEDIATELY IN THE FIELD. HOWEVER, SHORT-TERM REFRIGERATION AND LONGER-TERM PRESERVATION OF SIEVED SAMPLES WITH FORMALIN MAY BE ACCEPTABLE COMPROMISES.

FEDERLE, THOMAS W., ROBERT J. LIVINGSTON, DUANE A. MEETER, AND DAVID C. WHITE. 1983. MODIFICATIONS OF ESTUARINE SEDIMENTARY MICROBIOTA BY EXCLUSION OF EPIBENTHIC PREDATORS. J. EXP. MAR. BIOL. ECOL. 73(1):81-94. (ERL,GB 467*).

THE ABILITY OF EPIBENTHIC PREDATORS (CRABS AND FISHES) TO INFLUENCE BIOMASS AND COMMUNITY STRUCTURE OF SEDIMENTARY MICROBIOTA WAS INVESTIGATED IN ST. GEORGE SOUND-APALACHICOLA BAY SYSTEM, FLORIDA, U.S.A. REPLICATE AREAS (4 M SQUARED) OF MUD-FLAT SEDIMENT WERE CAGED IN THE FIELD TO CONFINE AND EXCLUDE PREDATORS. UNCAGED AREAS WERE USED AS CONTROLS. THE MICROBIOTA (PROKARYOTES AND MICROEUKARYOTES) OF THE SEDIMENTS WAS CHARACTERIZED AT WEEKS 0, 2, AND 6 BY MEASURING CONCENTRATIONS OF PHOSPHOLIPID AND ANALYZING FATTY ACIDS OF THE MICROBIAL LIPIDS EXTRACTED FROM THE SEDIMENTS. DATA WERE ANALYZED USING ANALYSIS OF VARIANCE AND STEP-WISE DISCRIMINANT ANALYSIS. AFTER 2 WK, THE MICROBIOTA OF THE PREDATOR EXCLUSION TREATMENT WAS SIGNIFICANTLY DIFFERENT FROM THAT IN CONTROL AND PREDATOR INCLUSION TREATMENTS. AFTER 6 WK, THESE DIFFERENCES BECAME MORE PRONOUNCED. THERE WERE NO DEMONSTRABLE CAGING EFFECTS THAT COULD ACCOUNT FOR TREATMENT DIFFERENCES. RESULTS INDICATED THAT REMOVAL OF PREDATORS HAD A PROFOUND EFFECT ON MICROBIAL COMMMUNITIES IN ESTUARINE SEDIMENTS. THUS, THE TOP TROPHIC LEVEL (EPIBENTHIC PREDATORS) HAD AN IMPORTANT ROLE IN REGULATING THE STRUCTURE OF THE LOWEST TROPHIC LEVEL (THE MICROBIOTA).

FEDERLE, THOMAS W., MEREDITH A. HULLAR, ROBERT J. LIVINGSTON, DUANE A. MEETER, AND DAVID C. WHITE. 1983. SPATIAL DISTRIBUTION OF BIOCHEMICAL PARAMETERS INDICATING BIOMASS AND COMMUNITY COMPOSITION OF MICROBIAL ASSEMBLIES IN ESTUARINE MUD FLAT SEDIMENTS. APPL. ENVIRON. MICROBIOL. 45(1):58-63. (ERL,GB X371*).
AVAIL. FROM NTIS, SPRINGFIELD, VA: PB83-223685.

THE SPATIAL DISTRIBUTION OF COMMUNITIES WAS EXAMINED IN ESTUARINE MUD FLAT SEDIMENTS BY THE BIOCHEMICAL ANALYSIS OF THE LIPIDS AND LIPID COMPONENTS EXTRACTED FROM THE SEDIMENTS. TOTAL PHOSPHOLIPID WAS USED AS A MEASURE OF TOTAL BIOMASS, AND FATTY ACIDS WERE USED AS INDICATORS OF COMMUNITY COMPOSITION. COMPARISONS WERE MADE AMONG 2- BY 2-M (LOCATION) AND 0.2- BY 0.2-M (CLUSTER) SAMPLING PLOTS BY USING A NESTED ANALYSIS OF VARIANCE TO DESIGN AN OPTIMAL SAMPLING STRATEGY TO DEFINE THE MICROBIAL CONTENT OF A LARGE, RELATIVELY HOMOGENOUS AREA. AT TWO OF THE THREE STATIONS, A 2- BY 2-M PLOT WAS REPRESENTATIVE OF THE STATION, BUT 0.2- BY 0.2-M AREAS WERE IN NO CASE REPRESENTATIVE OF THE STATION. THE BIOMASS MEASURED BY THE EXTRACTABLE PHOSPHOLIPID AND THE TOTAL LIPID PALMITIC ACID SHOWED EXCELLENT CORRELATION WITH THE FATTY ACID "SIGNATURES" CHARACTERISTIC OF BACTERIA, BUT SHOWED A LOWER CORRELATION WITH THE LONG-CHAIN POLYENOIC FATTY ACIDS CHARACTERISTIC OF THE MICROFAUNA.

FINDLAY, ROBERT H., AND DAVID C. WHITE. 1983. POLYMERIC BETA-HYDROXYALKANOATES FROM ENVIRONMENTAL SAMPLES AND BACILLUS MEGATERIUM. APPL. ENVIRON. MICROBIOL. 45(1):71-78. (ERL,GB X380*).

THE PROCARYOTIC ENDOGENOUS STORAGE POLYMER KNOWN AS POLY-BETA-HYDROXYBUTYRATE IS ACTUALLY A MIXED POLYMER OF SHORT-CHAIN BETA-HYDROXY FATTY ACIDS. A METHOD FOR THE QUANTITATIVE RECOVERY OF THIS MIXED POLYMER, CALLED POLY-BETA-HYDROXYALKANOATE (PHA), WITH ANALYSIS BY CAPILLARY GAS-LIQUID CHROMATOGRAPHY SHOWED THE PRESENCE OF AT LEAST 11 SHORT-CHAIN BETA-HYDROXY ACIDS IN POLYMERS EXTRACTED FROM MARINE SEDIMENTS. POLYMERS EXTRACTED FROM BACILLUS MEGATERIUM MONOCULTURES WERE ALSO A COMPLEX MIXTURE OF BETA-HYDROXY ACIDS WITH CHAIN LENGTHS BETWEEN FOUR AND EIGHT CARBONS. LYOPHILIZED SEDIMENTS WERE EXTRACTED IN A MODIFIED SOXHLET EXTRACTOR, AND THE POLYMER WAS PURIFIED WITH ETHANOL AND DIETHYL ETHER WASHES. THE PURIFIED POLYMER WAS TREATED WITH ETHANOL-CHLOROFORM-HYDROBCHLORIC ACID (8.5:2.5:1) FOR 4 H AT 100 DEGREES CELSIUS, A TREATMENT WHICH RESULTED IN THE FORMATION OF THE ETHYL ESTERS OF THE THE CONSTITUENT BETA-HYDROXY ACIDS. SUBSEQUENT ASSAY OF THE PRODUCTS BY GAS-LIQUID CHROMATOGRAPHY INDICATED EXCELLENT REPRODUCIBILITY AND SENSITIVITY (DETECTION LIMIT, 100 FMOL). DISTURBING SEDIMENTS MECHANICALLY OR ADDING NATURAL CHELATORS INCREASED ALL MAJOR PHA COMPONENTS RELATIVE TO THE BACTERIAL BIOAMSS. GARDENING OF SEDIMENTARY MICROBES BY CLYMENELLA SP., AN ANNELID WORM, INDUCED DECREASES IN PHA, WITH CHANGES IN THE RELATIVE PROPORTION OF COMPONENT BETA-HYDROXY ACIDS. THE CONCENTRATION OF PHA RELATIVE TO THE BACTERIAL BIOMASS CAN REFLECT THE RECENT METABOLIC STATUS OF THE MICROBIOTA.

FOX, F.R., AND K. RANGA RAO. 1982. ACCUMULATION, TISSUE DISTRIBUTION AND DEPURATION OF BENZO(A)PYRENE AND BENZ(A)ANTHRACENE IN THE GRASS SHRIMP, PALAEMONETES PUGIO. IN: SYMPOSIUM: CARCINOGENIC POLYNUCLEAR AROMATIC HYDROCARBONS IN THE MARINE ENVIRONMENT, PENSACOLA BEACH, FLORIDA, 14-18 AUGUST, 1978. EPA-600/9-82-013, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. PP. 336-349. (ERL,GB X237*).

THE SHORT-TERM UPTAKE, TISSUE DISTRIBUTION, AND DEPURATION OF TWO POLYCYCLIC AROMATIC HYDROCARBONS, C-14-BENZO(A)PYRENE (BP) AND C-14-BENZ(A)ANTHRACENE (BA), WERE STUDIED UTILIZING THE GRASS SHRIMP, PALAEMONETES PUGIO, AT KNOWN STAGES OF THE MOLT CYCLE. PREMOLT SHRIMP ACCUMULATED LESS BP AND BA THAN INTERMOLT SHRIMP. THE NEWLY MOLTED SHRIMP ACCUMULATED MORE BA THAN INTERMOLT SHRIMP. AT EACH OF THE CONCENTRATIONS TESTED [1.25, 2.5, 5.0, 10.0 PARTS PER BILLION (PPB)], INTERMOLT SHRIMP ACCUMULATED BY SHRIMP INCREASED IN RELATION TO ENVIRONMENTAL LEVELS OF THESE COMPOUNDS. THE ACCUMULATION OF BP AND BA IN TISSUES EXAMINED WAS IN THE FOLLOWING ORDER: DIGESTIVE TRACT (STOMACH + INTESTINE)> HEPATOPANCREAS> CEPHALOTHORAX> ABDOMEN. ALL TISSUES ACCUMULATED MORE BA THAN BP. WHEN EXPOSED TO MEDIA CONTAINING 2.5 PPB BP OR 2.8 PPB BA, A RAPID UPTAKE BY SHRIMP WAS NOTED DURING THE FIRST 6-HR EXPOSURE, SUBSEQUENTLY UPTAKE WAS REDUCED FOR BP. HOWEVER, AT TERMINATION OF 96-HR EXPOSURE, SHRIMP EXHIBITED A TREND OF CONTINUAL ACCUMULATION OF BA AND BP. WHEN TRANSFERRED TO SEAWATER, SHRIMP APPEARED TO DEPURATE BA MORE RAPIDLY THAN BP. IN THE SHRIMP EXPOSED TO BA, THE LEVEL OF RADIOACTIVITY DECLINED BY 80% AFTER A 7-DAY DEPURATION; UNDER SIMILAR CONDITIONS, THE BP LEVEL (RADIOACTIVITY) DECLINED BY ONLY 35%.

FOX, FERRIS R., AND K. RANGA RAO. 1978. CHARACTERISTICS OF A CA(2+) -ACTIVATED ATPASE FROM THE HEPATOPANCREAS OF THE BLUE CRAB, CALLINECTES SAPIDUS. COMP. BIOCHEM. PHYSIOL. B COMP. BIOCHEM. 59B(3):327-331. (ERL,GB X077*).

> 1. SOME CHARACTERISTICS OF A CALCIUM-ACTIVATED ATPASE IN THE MICROSOMAL FRACTION (48,000 G PELLET) OF THE HEPATOPANCREAS FROM THE BLUE CRAB, CALLINECTES SAPIDUS, ARE INVESTIGATED. 2. THE ENZYME REQUIRED A HIGH CONCENTRATION OF CA PLUS 2 (20 MM) FOR MAXIMAL ACTIVITY. K PLUS 1 WAS NOT REQUIRED FOR ACTIVATION. MG PLUS 2 WAS LESS EFFECTIVE THAN CA PLUS 2 IN ACTIVATING THE ATPASE. THE ENZYME WAS ALSO ACTIVATED BY SR PLUS 2 OR BA PLUS 2 ALONE. THE MAXIMAL ACTIVITY EVOKED BY SR PLUS 2 WAS GREATER THAN THAT EVOKED BY CA PLUS 2, WHILE BA PLUS 2 WAS A RELATIVELY POOR ACTIVATOR. 3. THE KM OF THE ENZYME FOR ATP WAS 4.1 X 10-3 M. IN A RANGE OF 20 TO 70 DEGREES C, THE MAXIMAL ACTIVITY WAS NOTED AT 45-50 DEGREES C. THE ENZYME EXHIBITED MAXIMAL ACTIVITY AT PH 7.5. 4. THE CHARACTERISTICS OF THE BLUE CRAB HEPATOPANCREATIC MICROSOMAL ENZYME ARE DIFFERENT FROM THOSE OF CRUSTACEAN MYOSIN ATPASES, BUT ARE COMPARABLE TO THOSE OF THE CA PLUS 2 -TRANSPORT ATPASES FROM OTHER ANIMALS.

FOX, FERRIS R., AND K. RANGA RAO. 1978. EFFECTS OF SODIUM PENTACHLOROPHENATE AND 2,4-DINITROPHENOL ON HEPATOPANCREATIC ENZYMES IN THE BLUE CRAB, CALLINECTES SAPIDUS. IN: PENTACHLOROPHENOL: CHEMISTRY, PHARMACOLOGY, AND ENVIRONMENTAL TOXICOLOGY. K. RANGA RAO, EDITOR, PLENUM PRESS, NEW YORK, NY. PP. 213-250. (ERL,GB X078*).

> IN VIEW OF THE LACK OF INFORMATION ON THE MECHANISMS OF PCP-INDUCED TOXICITY IN CRUSTACEANS, THIS INVESTIGATION WAS UNDERTAKEN TO EVALUATE THE EFFECTS OF SODIUM PENTACHLOROPHENATE (NA-PCP) IN VIVO AND IN VITRO ON CERTAIN HEPATOPANCREATIC ENZYMES IN THE BLUE CRAB, CALLINECTES SAPIDUS. FUMARASE, MALATE DEHYDROGENASE AND SUCCINATE DEHYDROGENASE WERE INHIBITED BY NA-PCP AND DNP IN VIVO, WHEREAS ISOCITRATE DEHYDROGENASE WAS STIMULATED. OF THOSE TESTED, LACTIC DEHYDROGENASE WAS THE LEAST AFFECTED CYTOPLASMIC (SOLUBLE) ENZYME IN VIVO WHILE PYRUVATE KINASE AND GLUCOSE-6-PHOSPHATE DEHYDROGENASE WERE INHIBITED AT LEAST 50% BY NA-PCP. GLUTAMATE-PYRUVATE TRANSAMINASE WAS ALSO INHIBITED. NA-PCP AND DNP HAD AN INHIBITORY EFFECT ON THE VARIOUS ENZYMES TESTED IN VITRO AT CONCENTRATIONS OF 10-4 M OR HIGHER. IN GENERAL, THE MITOCHONDRIAL ENZYMES WERE MORE SUSCEPTIBLE THAN CYTOPLASMIC ENYMES TO DNP AND NA-PCP. THE CALCIUM ACTIVATED ATPASE FROM THE MICROSOMAL FRACTION OF THE CRAB HEPATOPANCREAS WAS INHIBITED BY NA-PCP AND DNP IN VITRO AND IN VIVO. NA-PCP WAS MORE POTENT THAN DNP IN INHIBITING THE ATPASE ACTIVITY. THE EFFECTS OF PCP ON THE BLUE CRAB ENZYMES HAVE BEEN COMPARED TO THE RESULTS OF PREVIOUS INVESTIGATIONS ON OTHER ORGANISMS.

HAMILTON, P.V. 1980. SHELL SPINATION IN MELONGENA CORONA: SUBSPECIES CHARACTERISTIC OR SIZE RELATED?. MALACOL. REV. 13(1/2):84-86. (ERL,GB X313*).

> IT IS CONCLUDED THAT THE SIPHONAL SPINES OF MELINGENA CORONA ARE ACQUIRED ONTOGENETICALLY AND, CONSEQUENTLY, THAT THE POSSESSION OF SIPHONAL SPINES IS NOT A VALID MORPHOLOGICAL CHARACTER ON WHICH TO BASE A SUBSPECIES DISTINCTION IN THIS SPECIES. RECOGNITION OF THE DISTINCT SUBSPECIES M.C. CORONA AND M.C. JOHNSTONEI IS NOT WARRANTED, SINCE CLENCH & TURNER'S (1956) DISTINCTION IS BASED PRIMARILY ON THE PRESENCE OF SIPHONAL SPINES.

HAMILTON, PAUL V. 1981. BEHAVIORAL ASSAYS FOR EFFECTS OF DRILLING MUDS ON MARINE ANIMALS. EPA-600/4-81-050, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 52P.

THIS REPORT DESCRIBES AN ELECTRONIC METHOD FOR MONITORING THE SHELL MOVEMENTS AND WATER PUMPING OF BIVALVED MOLLUSCS, DATA ON THE INFLUENCE OF WHOLE DRILLING MUD AND OTHER PARTICULATE MATERIALS ON THE SHELL MOVEMENTS OF SCALLOPS (OBTAINED USING THE ELECTRONIC MONITOR), AND A SUBMERSIBLE MONITORING UNIT (SMU) FOR RECORDING THESE BEHAVIORS FROM BIVALVES HELD IN FIELD CONDITIONS. THE ELECTRONIC MONITOR EMPLOYS INTEGRATED CIRCUIT CHIPS AND RECEIVES INPUT FROM INDUCTANCE TRANSDUCER (SHELL MOVEMENTS) AND THERMISTOR (WATER PUMPING) SENSORS. WHOLE DRILLING MUD CAUSED SIGNIFICANTLY MORE MAJOR RAPID VALVE CLOSURES (RVC'S) AT CONCENTRATIONS OF 400 PPM AND HIGHER, AND A SIGNIFICANTLY GREATER CUMULATIVE MAGNITUDE OF ALL RVC'S AT 200 PPM AND HIGHER. BARITE, LIGNOSULPHONATE AND CALCIUM CARBONATE REVEALED NO CLEAR DOSE-RESPONSE RELATIONSHIP FOR THESE TWO SHELL MOVEMENT PARAMETERS, BUT ALL THREE OF THESE PARTICULATES PRODUCED SIMILAR PATTERNS OF EFFECT. THE SMU IS COMPLETELY SELF-CONTAINED; A BATTERY POWERED CIRCUIT AND TAPE RECORDER PERMIT RECORDING SHELL MOVEMENT DATA ON A MAGNETIC TAPE, WHICH IS LATER RETRIEVED FOR ANALYSIS.

HAMILTON, P.V., M.A. WINTER, AND R.K. PEGG. 1981. EFFECTS OF WHOLE DRILLING MUD AND SELECTED COMPONENTS ON THE SHELL MOVEMENTS OF THE BAY SCALLOP, ARGOPECTEN IRRADIANS. NORTHEAST GULF SCI. 5(1):13-20. (ERL,GB X348*). AVAIL. FROM NTIS, SPRINGFIELD, VA: PB82-238999.

THE SHELL MOVEMENTS OF BAY SCALLOPS (ARGOPECTEN IRRADIANS) WERE ELECTRONICALLY MONITORED BEFORE AND AFTER DIFFERENT AMOUNTS OF WHOLE DRILLING MUD, BARITE, LIGNOSULFONATE, AND CALCIUM CARBONATE WERE ADDED TO THEIR TANKS. MOVEMENTS WERE COMPARED WITH THOSE MADE BY SCALLOPS EXPOSED TO SEAWATER FOR THE SAME DURATION USING SIX RESPONSE MEASURES. FOR WHOLE DRILLING MUD, A GRADED DOSE-RESPONSE RELATIONSHIP EXISTED FOR TWO RESPONSE MEASURES: CHANGE IN THE NUMBER OF MAJOR RAPID VALVE CLOSURES (RVCS) AND CHANGE IN THE CUMULATIVE MAGNITUDE OF ALL RVCS. EJECTION OF PSEUDOFECES IS FREQUENTLY ASSOCIATED WITH RVCS. SCALLOPS TESTED SIMULTANEOUSLY WITH BARITE, LIGNOSULFONATE, AND CALCIUM CARBONATE SHOWED IRREGULAR BUT SIMILAR DOSE-RESPONSE RELATIONSHIPS FOR THESE TWO RESPONSE MEASURES. THREE OTHER MEASURES (CHANGES IN GAPE WIDTH, RVC MAGNITUDE, AND NUMBER OF ALL RVCS) WERE NOT RELIABLE INDICATORS OF RESPONSIVENESS FOR ANY MATERIALS. NONE OF THE MATERIALS CAUSED SIGNIFICANT CHANGES IN THE NUMBER OF SWIMMING ATTEMPTS, BUT ONLY ONE-THIRD OF THE ANIMALS EVER ATTEMPTED TO SWIM. SCALLOPS EXPOSED TO SEAWATER SHOWED NO SIGNIFICANT CHANGE FOR ANY RESPONSE MEASURE.

KENDALL, J.J., E.N. POWELL, S.J. CONNOR, AND T.J. BRIGHT. 1983. EFFECTS OF DRILLING FLUIDS (MUDS) AND TURBIDITY ON THE GROWTH AND METABOLIC STATE OF THE CORAL ACROPORA CERVICORNIS, WITH COMMENTS ON METHODS OF NORMALIZATION FOR CORAL DATA. BULL. MAR. SCI. 33(2):336-352. (ERL,GB X396).

THE EFFECTS OF A USED DRILLING MUD ON CORAL HEALTH HAVE BEEN EXAMINED BY MONITORING CHANGES IN CALCIFICATION RATE, SOLUBLE TISSUE PROTEIN CONCENTRATION AND TOTAL NINHYDRIN POSITIVE SUBSTANCE (NPS) CONCENTRATION IN THE CORAL ACROPORA CERVICORNIS. EXPOSURE TO A USED DRILLING MUD REDUCED CALCIFICATION RATE IN GROWING TIPS BY 62%, 83% AND 88% AT 25 PPM, 50 PPM AND 100 PPM (V/V), RESPECTIVELY AFTER A 24-H EXPOSURE PERIOD. SOLUBLE TISSUE PROTEIN CONCENTRATION DROPPED SIGNIFICANTLY IN THE GROWING TIP AFTER 24 H EXPOSURE TO A SOLUTION OF 25-, 50-, 100- AND 500-PPM DRILLING MUD FOR 24 H. EQUIVALENT CONCENTRATIONS OF KAOLIN (TO PRODUCE TURBIDITY) CAUSED NO DROP IN BPS OR PROTEIN CONCENTRATION AND A MUCH LOWER DROP IN CALCIFICATION RATE SUGGESTING THAT THE TOXIC EFFECTS OBSERVED FOR THE DRILLING MUD USED WERE NOT CAUSED BY AN INCREASE IN TURBIDITY ALONE. THE SIGNIFICANT DROP IN PROTEIN CONCENTRATION SUGGESTS THAT THE USE OF PROTEIN OR OTHER TISSUE COMPONENTS FOR NORMALIZATION IN CORALS MAY NOT BE JUSTIFIED IN SOME CASES AND SHOULD BE VIEWED WITH CAUTION.

KENDALL, J.J., JR., E.N. POWELL, S.J. CONNOR, T.J. BRIGHT, AND C.E. ZASTROW. 1984. IMPORTANCE OF MONITORING METABOLIC RECOVERY IN THE CORAL ACROPORA CERVICORNIS AFTER SHORT-TERM EXPOSURE TO DRILLING MUDS: CALCIFICATION RATE AND PROTEIN CONCENTRATION. CORAL REEFS. 2:215-225. (ERL,GB X008).

THE EFFECT OF USED DRILLING MUDS ON CORAL HEALTH WAS EXAMINED BY MONITORING CHANGES IN CALCIFICATION RATE AND SOLUBLE TISSUE PROTEIN CONCENTRATION IN THE CORAL ACROPORA CERVICORNIS. EXPOSURE TO 25 PPM (V/V) OF ONE MUD FOR 24 H REDUCED CALCIFICATION RATE IN THE GROWING TIPS BY AS MUCH AS 62%. IN RECOVERY EXPERIMENTS, CORALS WERE EXPOSED TO DRILLING MUDS FOR 24 H; SOME OF THERE WERE ALLOWED TO RECOVER IN CLEAN SEAWATER FOR 48 H. AFTER THE 24-HOUR EXPOSURE, CALCIFICATION RATES WERE SIGNIFICANTLY LESS THAN THOSE OF THE CONTROLS. AFTER A 48-HOUR RECOVERY PERIOD, CALCIFICATION RATES RETURNED TO CONTROL LEVELS FOR ONE MUD BUT WERE STILL SIGNIFICANTLY BELOW CONTROL LEVELS FOR ANOTHER. THE RESULTS INDICATE THAT THE CAPACITY FOR RECOVERY AFTER EXPOSURE CANNOT BE PREDICTED FROM THE RESULTS OF EXPERIMENTS ON EXPOSURE ONLY. RECOVERY CAPACITY MUST BE INDEPENDENTLY VERIFIED FOR ALL STUDIES ON THE EFFECTS OF SHORT-TERM EXPOSURE TO DRILLING MUDS.

KOENIG, MICHAEL L., ERIC N. POWELL, AND MARGARET R. KASSCHAU. 1981. EFFECTS OF SALINITY CHANGE ON THE FREE AMINO ACID POOLS OF TWO NEREID POLYCHAETES, NEANTHES SUCCINEA AND LEONEREIS CULVERI. COMP. BIOCHEM. PHYSIOL. A COMP. PHYSIOL. 70A(4):631-637. (ERL,GB X413).

1. THE RESPONSE OF THE FREE AMINO ACID POOLS OF TWO NEREID POLYCHAETES, NEANTHES SUCCINEA AND LAEONEREIS CULVERI TO BOTH INCREASED AND DECREASED SALINITIES WAS EXAMINED. IN BOTH SPECIES, GLYCINE AND ALANINE ACCOUNTED FOR MOST OF THE OBSERVED CHANGE IN THE TOTAL FREE AMINO ACID (FAA) POOL SIZE. 2. GLUTAMINE VALUES INCREASED UNDER HYPO-OSMOTIC CONDITIONS SUGGESTING THAT THIS AMINO ACID PLAYS A ROLE IN NITROGEN STORAGE DURING THE REDUCTION IN FAAS WHICH OCCURS WITH REDUCED SALINITY. 3. THE SALINITY REPSONSE WAS SUPERIMPOSED ON A "LABORATORY STRESS" RESPONSE CHARACTERIZED BY A GENERALIZED INCREASE IN THE FAA POOL SIZE. THE TWO RESPONSES APPEARED TO BE ADDITIVE IN NATURE. 4. SIGNIFICANT DIFFERENCES IN THE RESPONSES TO SALINITY CHANGE IN NEREID POLYCHAETES.

KRONE, M.A., AND D.C. BIGGS. 1980. SUBLETHAL METABOLIC RESPONSES OF THE HERMATYPIC CORAL MADRACIS DECACTIS EXPOSED TO DRILLING MUD ENRICHED WITH FERROCHROME LIGNOSULFONATE. IN: SYMPOSIUM: RESEARCH ON ENVIRONMENTAL FATE AND EFFECTS OF DRILLING FLUIDS AND CUTTINGS, JANUARY 21-24, 1980, LAKE BUENA VISTA, FL., VOL. 2. AMERICAN PETROLEUM INSTITUTE, WASHINGTON, DC. PP. 1097-1100. (ERL,GB X167*).

MADRACIS DECACTIS CORALS WERE EXPOSED FOR 17 DAYS IN LABORATORY AQUARIA TO SUSPENSIONS OF 100 PPM DRILLING MUD OBTAINED APRIL 1979 FROM A WORKING DRILL RIG IN MOBILE BAY, ALABAMA, AND SPIKED IN THE LABORATORY WITH 0, 3, AND 10 PPM FERROCHROME LIGNOSULFONATE (FCLS). DURING THE FIRST WEEK OF EXPOSURE TO DRILL MUD + FCLS, CORALS INCREASED THEIR OXYGEN CONSUMPTION AND AMMONIUM EXCRETION, RELATIVE TO UNCONTAMINATED CONTROLS. THOSE CORALS EXPOSED TO THE HIGHEST ENRICHMENTS OF FCLS DEMONSTRATED THE GREATEST INCREASES IN RESPIRATION AND EXCRETION AND ALSO THE LARGEST VARIATIONS IN RESPIRATION AND EXCRETION BETWEEN INDIVIDUAL CORALS. CORALS REACHED THEIR HIGHEST AVERAGE RATES OF RESPIRATION AND EXCRETION BY THE END OF THE FIRST WEEK AND, AFTER A SECONDARY INCREASE IN EXCRETION AND RESPIRATION BETWEEN DAYS 10-13 WHICH WAS MOST PRONOUNCED IN THOSE CORALS EXPOSED TO FCLS ENRICHMENT, LEVELED OFF AT NEAR-INITIAL RATES BY THE END OF THE SECOND WEEK. ANALYSIS OF VARIANCE DEMONSTRATED THAT OXYGEN CONSUMPTION OF FCLS-STRESSED CORALS WAS NOT STATISTICALLY DIFFERENT ($P = 0.24$) FROM UNCONTAMINATED CONTROL CORALS. BY CONTRAST, AMMONIUM EXCRETION WAS SIGNIFICANTLY GREATER ($P = 0.10$) IN FCLS-STRESSED CORALS THAN IN UNCONTAMINATED CONTROL ANIMALS. ALL CORALS EXPOSED TO FCLS REACTED BY REDUCING THEIR DEGREE OF POLYP EXPANSION. TWO OF THESE, ONE EXPOSED TO 100 PPM DRILL MUD + 3 PPM FCLS AND THE OTHER TO 100 PPM DRILL MUD + 10 PPM FCLS BECAUSE BACTERIALLY INFECTED AND SHOWED LOCAL AREAS OF POLYP MORTALITY AS THE EXPERIMENT ENTERED ITS SECOND WEEK. THESE WERE THE TWO CORALS WHICH HAD SHOWN THE MOST RAPID AND MOST CONSISTENT INCREASES IN EXCRETION AND RESPIRATION DURING THE FIRST WEEK OF EXPOSURE TO FCLS. WHEN EXPOSURE TO DRILL MUD + FCLS WAS DISCONTINUED, RESPIRATION AND EXCRETION OF SURVIVING CORALS REMAINED LOW AND STABLE WHILE THEIR POLYP ACTIVITY RETURNED TO NORMAL LEVELS WITHIN 48 HOURS.

KRONE, MICHAEL A. 1981. SUBLETHAL METABOLIC RESPONSES OF THE HERMATYPIC CORAL MADRACIS DECACTIS EXPOSED TO DRILLING MUD ENRICHED WITH FERROCHROME LIGNOSULFONATE;- FINAL REPORT. EPA-600/4-81-049, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 67P.

MADRACIS DECATIS CORALS WERE EXPOSED FOR 17 DAYS IN LABORATORY AQUARIA TO SUSPENSIONS OF 100 PPM DRILLING MUD SPIKED WITH 0, 3, AND 10 PPM FERROCHROME LINGOSULFONATE (FCLS). DURING THE FIRST WEEK OF EXPOSURE, THESE CORALS INCREASED THEIR OXYGEN CONSUMPTION AND AMMONIUM EXCRETION, RELATIVE TO UNCONTAMINATED CONTROLS. THOSE CORALS EXPOSED TO THE HIGHEST ENRICHMENTS OF FCLS DEMONSTRATED THE GREATEST INCREASES IN RESPIRATION AND EXCRETION AND ALSO THE LARGEST VARIATIONS IN RESPIRATION AND EXCRETION BETWEEN INDIVIDUAL EXPERIMENTAL ANIMALS. CORALS REACHED THEIR HIGHEST AVERAGE RATES OF RESPIRATION AND EXCRETION BY THE END OF THE FIRST WEEK OF CONTINUOUS EXPOSURE. RATES THEN DECREASED DURING THE NEXT WEEK AND, AFTER A SECONDARY INCREASED IN EXCRETION AND RESPIRATION BETWEEN DAYS 10-13 WHICH WAS MOST PRONOUNCED IN THOSE CORALS EXPOSED TO FCLS ENRICHMENT, LEVELED OFF AT NEAR-INITIAL RATES BY THE END OF THE SECOND WEEK. TWO CORALS, ONE EXPOSED TO 100 PPM DRILL MUD PLUS 3 PPM FCLS AND THE OTHER TO 100 PPM DRILL MUD PLUS 10 PPM FCLS, BECAME NOTICEABLY MORIBUND AS THE EXPERIMENT ENTERED ITS SECOND WEEK. THESE WERE THE TWO CORALS WHICH SHOWED THE MOST RAPID AND MOST CONSISTENT INCREASED IN EXCRETION AND RESPIRATION DURING THE FIRST WEEK OF EXPOSURE TO FCLS. BY WEEK TWO, POLYP EXPANSION IN BOTH OF THESE CORALS WAS DRAMATICALLY REDUCED, AND EACH WAS REMOVED FROM THE EXPERIMENT WHEN AREAS OF BARE CORALLUM SUGGESTED THE ONSET OF POLYP DEATH. ALL CORALS EXPOSED TO FCLS REACTED BY REDUCING THEIR POLYP EXPANSION BEHAVIOR, ALTHOUGH ONLY THE TWO CITED ABOVE SHOWED MASS POLYP MORTALITY. WHEN EXPOSURE TO DRILL MUD PLUS FCLS WAS DISCONTINUED, RESPIRATION AND EXCRETION OF SURVIVING CORALS REMAINED LOW AND STABLE WHILE THEIR POLYP ACTIVITY RETURNED TO NORMAL LEVELS WITHIN 48 HOURS.

LEHMAN, H.K., AND P.V. HAMILTON. 1980. SOME FACTORS INFLUENCING THE DISTRIBUTION OF THE SNAIL NERITINA RECLIVATA. NORTHEAST GULF SCI. 4(1):67-72. (ERL,GB X269*).

THE GASTROPOD FAMILY NERITIDAE CONTAINS OVER 200 LIVING SPECIES, MOST OF WHICH INHABIT INTERTIDAL ZONES IN TROPICAL AND TEMPERATE CLIMATES. THE OLIVE NERITE, NERITINA RECLIVATA SAY, IS IRREGULARLY DISTRIBUTED ALONG COASTAL REGIONS OF THE GULF OF MEXICO AND THE CARIBBEAN SEA FROM 10 TO 30 DEGREES N LATITUDE. ITS DISTRIBUTION ENDS IN THE NORTH AT JACKSONVILLE, FLORIDA ON THE ATLANTIC OCEAN AND IN THE SOUTH AT TRINIDAD (RUSSELL, 1941). MOST RECORDS OF N. RECLIVATA ARE FROM COASTAL REGIONS OF THE GULF OF MEXICO, BUT THIS MAY BE DUE TO THE PAUCITY OF FAUNAL SURVEYS ELSEWHERE IN ITS RANGE. DESPITE THE COMMON OCCURRENCE OF N. RECLIVATA, IT REMAINS VIRTUALLY UNSTUDIED. RUSSELL (1941) REPORTED THAT N. RECLIVATA INHABITS BRACKISH AND FRESHWATER, AND IS ABSENT FROM MANY SMALL ISLANDS IN THE ANTILLES THAT DO NOT SUPPORT PERMANENT FRESHWATER RIVERS. ACCORDING TO THIS AUTHOR, N. RECLIVATA IS FOUND ON SOLID SUBSTRATES IN THE WATER, BUT NOT ON THE MUD. N. RECLIVATA CRAWLS USING MONOTAXIC RETROGRADE WAVES, A TYPE OF LOCOMOTION OFTEN FOUND IN SPECIES LIVING ON SOLID SUBSTRATE (GAINEY, 1976). PILSBRY (1931) NOTED THE SNAIL'S PRESENCE ON REEDS AND OTHER AQUATIC PLANTS NEAR DRAINAGE CANALS AND SUGGESTED THAT ALGAE MAY COMPRISE THE FOOD OF THE SNAIL. WE HAVE COLLECTED N. RELIVATA FROM HARD SUBSTRATES (E.G., PLANTS, STUMPS, ROCKS) AT LOCATIONS BETWEEN 5 KM UP THE ESCAMBIA RIVER AND THE WESTERN TIP OF THE GULF BREEZE PENINSULA, SANTA ROSA COUNTY, FLORIDA. THESE LOCATIONS CORRESPOND TO A SALINITY RANGE OF 1 TO 19 PPT (U.S. ENVIRONMENTAL PROTECTION AGENCY, 1975). BECAUSE OUR PRELIMINARY OBSERVATIONS SUGGESTED AN AFFINITY OF NERITINA FOR SOLID SUBSTRATES, WE INVESTIGATED THIS RELATIONSHIP TO DETERMINE ITS ECOLOGICAL BASIS.

MORRISON, S.J., AND D.C. WHITE. 1980. EFFECTS OF GRAZING BY ESTUARINE GAMMARIDEAN AMPHIPODS ON THE MICROBIOTA OF ALLOCHTHONOUS DETRITUS. APPL. ENVIRON. MICROBIOL. 40(3):659-671. (ERL,GB X187*).

ESTUARINE GAMMARIDEAN AMPHIPODS GRAZING AT NATURAL POPULATION DENSITY ON DETRITAL MICROBIOTA AFFECTED THE MICROBIAL COMMUNITY COMPOSITION, BIOMASS, AND METABOLIC ACTIVITY WITHOUT AFFECTING THE PHYSICAL STRUCTURE OF THE LEAVES. TOTAL MICROBIAL BIOMASS ESTIMATED BY ADENOSINE TRIPHOSPHATE AND LIPID PHOSPHATE OR OBSERVED BY SCANNING ELECTRON MICROSCOPY WAS GREATER ON GRAZED THAN ON UNGRAZED DETRITUS. THE RATES OF OXYGEN CONSUMPTION, POLY-B-HYDROXYBUTYRATE SYNTHESIS, TOTAL LIPID BIOSYNTHESIS, AND RELEASE OF CO2-14 FROM RADIOACTIVELY PRELABELED MICROBIOTA WERE HIGHER ON GRAZED THAN ON UNGRAZED LEAVES, INDICATING STIMULATION OF THE METABOLIC ACTIVITY OF GRAZED DETRITAL MICROBES. THIS WAS TRUE WITH RATES BASED EITHER ON THE DRY LEAF WEIGHT OR MICROBIAL BIOMASS. THERE WAS A FASTER INCREASE IN THE C-14-GYCLOLIPID THAN IN THE C-14-NEUTRAL LIPID OR C-14-PHOSPHOLIPID FRACTIONS. ANALYSIS OF SPECIFIC PHOSPHOLIPIDS SHOWED LOSSES OF THE METABOLICALLY STABLE [C-14]GLYCEROLPHOSPHORYLGLYCEROL WITH AMPHIPOD GRAZING. THE BIOCHEMICAL DATA SUPPORTED SCANNING ELECTRON MICR-OSCOPY OBSERVATIONS OF A SHIFT AS THE GRAZING PROCEEDED FROM A BACTERIAL/FUNGAL COMMUNITY TO ONE DOMINATED BY BACTERIA.

NEFF, JERRY M. 1981. FATE AND BIOLOGICAL EFFECTS OF OIL WELL DRILLING FLUIDS IN THE MARINE ENVIRONMENT: A LITERATURE REVIEW. EPA-600/3-82-064, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 150P.

THE MAJOR ENVIRONMENTAL CONCERNS ABOUT DISCHARGE OF USED DRILLING MUDS TO THE OCEAN ARE THAT THEY MAY BE ACUTELY TOXIC OR CAUSE DELETERIOUS SUBLETHAL EFFECTS IN SENSITIVE ORGANISMS AND ECOSYSTEMS AND THAT HEAVY METALS ASSOCIATED WITH DRILLING MUDS MAY BE ACCUMULATED BY MARINE ORGANISMS TO DANGEROUS CONCENTRATIONS. A MAJORITY OF MAJOR DRILLING MUD INGREDIENTS ARE BIOLOGICALLY INERT OR HAVE A VERY LOW ORDER OF ACUTE TOXICITY. OF THE MAJOR DRILLING MUD INGREDIENTS, ONLY CHROME- AND FERROCHROME-LIGNOSULFONATES CAN BE CONSIDERED AT ALL TOXIC. THEIR TOXICITY IS QUITE LOW TO ALL BUT A FEW SENSITIVE SPECIES (E.G., SOME CORALS). MINOR INGREDIENTS OF SOME ENVIRONMENTAL CONCERN INCLUDE SODIUM PHOSPHATE SALTS, DETERGENTS, BIOCIDES (CHLORINATED PHENOLS NO LONGER ARE PERMITTED FOR OFFSHORE DISPOSAL), CHROMATE SALTS AND ASPHALT/OIL-BASED INGREDIENTS. ORDINARILY, THESE MATERIALS ARE NOT USED IN LARGE ENOUGH QUANTITIES TO CAUSE CONCERN. THEIR CONCENTRATIONS SHOULD BE KEPT LOW IN DRILLING MUDS DESTINED FOR OCEAN DISPOSAL. WHERE POSSIBLE, LESS TOXIC SUBSTITUTES SHOULD BE USED. TO DATE, THE ACUTE TOXICITY AND SUBLETHAL BIOLOGICAL EFFECTS OF MORE THAN 20 USED OFFSHORE-TYPE DRILLING MUDS HAVE BEEN EVALUATED WITH MORE THAN 60 SPECIES OF MARINE ANIMALS FROM THE ATLANTIC, PACIFIC, GULF OF MEXICO AND BEAUFORT SEA. REPRESENTATIVES OF FIVE MAJOR ANIMAL PHYLA HAVE BEEN TESTED, INCLUDING CHORDATA, ARTHROPODA, MOLLUSCA, ANNELIDA AND ECHINODERMATA. LARVAE AND OTHER EARLY LIFE STAGES, AND OCEANIC SPECIES (CONSIDERED TO BE MORE SENSITIVE TAN ADULTS AND ESTUARINE SPECIES TO POLLUTANT STRESS) WERE INCLUDED. IN ALL BUT A FEW CASES, ACUTE TOXICITY, USUALLY MEASURED AS 96-HR. LC50, WAS 10,000 PPM OR HIGHER DRILLING MUD ADDED. THE LOWEST ACUTE LC50 VALUE WAS 500 PPM FOR STAGE I LARVAE OF DOCK SHRIMP PANDALUS DANAE EXPOSED TO A HIGH DENSITY FERROCHROME LIGNOSULFONATE DRILLING MUD FROM COOK INLET, ALASKA. CHRONIC OR SUBLETHAL RESPONSES WERE OBSERVED IN A FEW CASES AT CONCENTRATIONS AS LOW AS 50 PPM.

NEW ENGLAND AQUARIUM, BOSTON, MA. 1984. SURVEY OF THE TOXICITY AND CHEMICAL COMPOSITION OF USED DRILLING MUDS. EPA-600/X-84-083, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 109P.

CHEMICAL CHARACTERIZATION AND TOXICITY OF OIL DRILLING FLUIDS WERE INVESTIGATED BY EDGERTON RESEARCH LABORATORY FROM OCT. 1, 1979 TO AUG., 1983 AS PART OF A COMPREHENSIVE RESEARCH PROGRAM SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY TO DETERMINE FATE AND EFFECTS OF SUCH FLUIDS IN THE MARINE ENVIRONMENT. DRILLING MUDS USED WERE SUPPLIED BY EPA, THE PETROLEUM EQUIPMENT SUPPLIERS ASSOCIATION, AND THE AMERICAN PETROLEUM INSTITUTE. THE DRILLING MUDS WERE DESIGNATED "MAY 15," "MAY 29," "SEPT. 4," "EXXON," "GILSON," "MOBILE BAY," "JAY FIELD," AND "PESA." INVESTIGATIONS DURING THE FIRST YEAR CENTERED ON THE CHEMICAL COMPOSITION AND ACUTE TOXICITY OF DRILLING MUDS, AND THE EFFECTS OF DRILLING MUDS ON RECRUITMENT OF BENTHIC ORGANISMS. IN THE SECOND YEAR, STUDIES FOCUSED ON TOXICITY TESTING WITH PLANKTONIC COPEPODS, CHEMICAL CHARACTIERIZATION OF TOXICITY TEST PHASES, BIOACCUMULATION STUDIES, AND EFFECTS OF MUDS ON LARVAL AND ADULT BENTHIC ORGANISMS. INVESTIGATIONS DURING THE THIRD AND FOURTH YEAR EXAMINED SUBLETHAL EFFECTS OF DRILLING FLUIDS ON CLAM LARVAE, TRACE METAL AND ORGANIC CONSTITUENTS IN BOTH DRILLING FLUIDS AND TOXICITY TEST-PHASES, AND PRELIMINARY DEVELOPMENT OF A DRILLING FLUID SOLID PHASE TOXICITY TEST. TOXIC COMPONENTS OF USED DRILLING MUDS TESTED WERE PRESENT AS DISSOLVED COMPONENTS OR ASSOCIATED WITH VERY SLOWLY SETTLING PARTICLES. SOME USED DRILLING MUDS CONTAINED LIPOPHILIC FRACTIONS THAT WERE SIMILAR TO HYDROCARBONS FOUND IN #2 FUEL OIL IN THE LIQUID FRACTION AND SUSPENDED PARTICULATES FRACTION AND CONTAINED #2 FUEL OIL IN WHOLE MUDS. MUDS THAT CONTAINED THOSE COMPONENTS WERE MORE TOXIC THAN THOSE THAT DID NOT. JUVENILE COPEPODS (ACARTIA TONSA) WERE NOT MORE SENSITIVE TO TOXIC DRILLING MUD SOLUTIONS THAN ADULTS OF THIS SPECIES. IN GENERAL, CANCER IRRORATUS LARVAE APPEARED TO EXHIBIT TOXICITY RESPONSES TO DRILLING MUDS THAT WERE SIMILAR TO COPEPODS TESTED. ARRESTED SHELL DEVELOPMENT INDUCED BY EXPOSURE TO DRILLING MUDS APPEARED TO BE A SENSITIVE INDICATOR OF STRESS IN BIVALVE LARVAE. TOTAL CHROMIUM CONCENTRATION SHOWED NO CORRELATION TO TOXICITY IN DRILLING MUDS THAT WERE TESTED; HOWEVER, THE HIGHEST CONCENTRATIONS OF CR(VI), THE MOST BIOLOGICALLY TOXIC FORM OF CHROMIUM, OCCURRED IN TEST PHASES THAT EXHIBITED THE GREATEST TOXICITY TO MERCENARIA MERCENARIA LARVAE. THE MUDS DESIGNATED "MAY 15" AND "SEPT. 4" APPEARED TO BE RELATIVELY NON-TOXIC TO PSEUDOPLEURONECTES AMERICANUS AND TO MENIDIA MENIDIA, ALTHOUGH THE "MAY 15" MUD WAS TOXIC TO NEOMYSIS AMERICANA AND TO ACARTIA TONSA. A STUDY OF EFFECTS OF DRILLING MUD ON INVERTEBRATE RECOLONIZATION OF DEFAUNATED SEDIMENT SHOWED THAT RECOLONIZATION DECREASED IN DRILLING MUD LAYERED ON TOP OF SEDIMENT WHEN MUDS WERE MIXED WITH SEDIMENTS. CAPITELLA CAPITATA WAS MUCH MORE NUMEROUS IN RECOLONIZATION SEDIMENTS THAT CONTAINED DRILLING MUD. TEST RESULTS SHOWED THAT METHODS USED TO PREPARE DRILLING MUD TEST MEDIA AFFECT THE APPARENT TOXICITY OF THE MUDS.

NICKELS, J.S., R.J. BOBBIE, R.F. MARTZ, G.A. SMITH, D.C. WHITE, AND N.L. RICHARDS. 1981. EFFECT OF SILICATE GRAIN SHAPE, STRUCTURE, AND LOCATION ON THE BIOMASS AND COMMUNITY STRUCTURE OF COLONIZING MARINE MICROBIOTA. APPL. ENVIRON. MICROBIOL. 41(5):1262-1268. (ERL,GB X190*).

MICROBIOTA COLONIZING SILICA GRAINS OF THE SAME SIZE AND WATER PORE SPACE, BUT WITH A DIFFERENT MICROTOPOGRAPHY, SHOWED DIFFERENCES IN BIOMASS AND COMMUNITY STRUCTURE AFTER 8 WEEKS OF EXPOSURE TO RUNNING SEAWATER. THE ABSENCE OF SURFACE CRACKS AND CREVICES RESULTED IN A MARKED DIMINUTION OF THE TOTAL MICROBIAL BIOMASS MEASURED AS LIPID PHOSPHATE AND TOTAL EXTRACTABLE PALMITIC ACID. WITH INCREASING SMOOTHNESS OF THE SAND GRAIN SURFACE, EXAMINATION OF THE COMMUNITY STRUCTURE SHOWED A MARKED DECREASE IN PROCARYOTES AND ALGAL MICROEUCARYOTES, WITH A RELATIVE INCREASE IN MICROEUCARYOTIC GRAZERS. A COMPARISON OF THE COLONIZING SEDIMENT INCUBATED IN RUNNING SEAWATER OR AT 32 M ON THE SEA FLOOR WITH A SEDIMENT CORE SHOWED A DECREASED BACTERIAL BIOMASS WITH A DIFFERENT COMMUNITY STRUCTURE AND A DECREASED TOTAL MICROEUCARYOTIC POPULATION OF BOTH GRAZERS AND ALGAE. THE QUANTITATIVE DIFFERENCES IN MICROBIAL BIOMASS AND COMMUNITY STRUCTURE BETWEEN THE MICROCOSMS AND THE ACTUAL BENTHIC POPULATION IN THE CORE WERE DETERMINED.

PARKER, JEFFREY H., GLEN A. SMITH, HERBERT L. FREDRICKSON, J. ROBIE VESTAL, AND DAVID C. WHITE. 1982. SENSITIVE ASSAY, BASED ON HYDROXY FATTY ACIDS FROM LIPOPOLYSACCHARIDE LIPID A, FOR GRAM-NEGATIVE BACTERIA IN SEDIMENTS. APPL. ENVIRON. MICROBIOL. 44(5):1170-1177. (ERL,GB X338*).
AVAIL. FROM NTIS, SPRINGFIELD, VA: PB83-223693.

BIOCHEMICAL MEASURES HAVE PROVIDED INSIGHT INTO THE BIOMASS AND COMMUNITY STRUCTURE OF SEDIMENTARY MICROBIOTA WITHOUT THE REQUIREMENT OF SELECTION BY GROWTH OR QUANTITATIVE REMOVAL FROM THE SEDIMENT GRAINS. THIS STUDY USED THE ASSAY OF THE HYDROXY FATTY ACIDS RELEASED FROM THE LIPID A OF THE LIPOPOLYSACCHARIDE IN SEDIMENTS TO PROVIDE AN ESTIMATE OF THE GRAM-NEGATIVE BACTERIA. THE METHOD WAS SENSITIVE TO PICOMOLAR AMOUNTS OF HYDROXY FATTY ACIDS. THE RECOVERY OF LIPOPOLYSACCHARIDE HYDROXY FATTY ACIDS FROM ORGANISMS ADDED TO SEDIMENTS WAS QUANTITATIVE. THE LIPIDS WERE EXTRACTED FROM THE SEDIMENTS WITH A SINGLE-PHASE CHLOROFORM-METHANOL EXTRACTION. THE LIPID-EXTRACTED RESIDUE WAS HYDROLYZED IN 1 N HCL, AND THE HYDROXY FATTY ACIDS OF THE LIPOPOLYSACCHARIDE WERE RECOVERED IN ABOUT FIVEFOLD MORE SENSITIVE THAN THE CLASSICAL PHENOL-WATER OF TRICHLOROACETIC ACID METHODS WHEN APPLIED TO MARINE SEDIMENTS. BY EXAMINATION OF THE PATTERNS OF HYDROXY FATTY ACIDS, IT WAS ALSO POSSIBLE TO HELP DEFINE THE COMMUNITY STRUCTURE OF THE SEDIMENTARY GRAM-NEGATIVE BACTERIA.

PARKER, JEFFREY H., JANET S. NICKELS, ROBERT F. MARTZ, MICHAEL J. GEHRON, NORMAN L. RICHARDS, AND DAVID C. WHITE. 1984. EFFECT OF WELL-DRILLING FLUIDS ON THE PHYSIOLOGICAL STATUS AND MICROBIAL INFECTION OF THE REEF BUILDING CORAL MONTASTREA ANNULARIS. ARCH. ENVIRON. CONTAM. TOXICOL. 13(1):113-118. (ERL,GB X382).

THE REEF BUILDING CORAL MONTASTREA ANNULARUS WAS EXPOSED CONTINUOUSLY TO SUSPENSIONS OF OIL AND GAS-WELL DRILLING FLUIDS AT CONCENTRATIONS OF 0.1 ML LITER(-1), 0.01 ML LITER(-1), AND 0.0001 ML LITER(-1) IN FLOWING SEAWATER AT THE U.S. NAVAL STAGE I PLATFORM (30 DEGREES 7.5' N, 85 DEGREES 46.3' W). AFTER 6 WEEKS EXPOSURE, CORAL FRAGMENTS OF 12 TO 65 CM(2) SURFACE AREA WERE BROKEN OFF, RINSED IN SEAWATER, AND EXTRACTED IN A ONE-PHASE CHLOROFORM-METHANOL-BUFFER AND RETURNED TO THE LABORATORY. IN THE LABORATORY, THE EXTRACTION WAS COMPLETED AND THE PHASES SEPARATED. THE LIPIDS WERE FRACTIONATED USING SILICIC ACID AND THIN LAYER CHROMATOGRAPHY. TOTAL PHOSPHOLIPID, TRIGLYCERIDE GLYCEROL, TOTAL EXTRACTABLE FATTY ACIDS, TRIGLYCERIDE FATTY ACIDS AS WELL AS THE ESTER FATTY ALCOHOLS SHOWED NO CONSISTENT CHANGES WITH EXPOSURE TO THE DRILLING FLUIDS. CHANGES IN FREE AMINO ACID CONCENTRATIONS WERE EXTRACTED AS WELL AS SIGNIFICANT DECREASES IN THE RECOVERABLE DIACYL PHOSPHOLIPID. SIGNIFICANT INCREASES IN PLASMALOGEN PHOSPHOLIPIDS APPEARED WITH EXPOSURE. INCREASES IN PLASMALOGEN PHOSPHOLIPIDS ARE CONSISTENT WITH INFECTION BY ANAEROBIC FERMENTING BACTERIA WHICH CAN INDICATE DISEASE. THIS EVIDENCE SUGGESTS THAT BIOCHEMICAL INDICATORS OF INFECTION WITH ANAEROBIC BACTERIA MAY BE USEFUL AS SENSITIVE MARKERS FOR POLLUTION-INDUCED CHANGES IN REEF BUILDING CORALS AND THUS FOR MONITORING THE HEALTH OF CORAL REEFS.

PARSONS, DEAN, TOM BURKE, TERRY HIGHT, NORMAN RICHARDS, AND SUZANNE BOLTON, 1980. DRILLING MUD RESEARCH--OVERSIGHT. IN: OCEANOGRAPHY MISCELLANEOUS--PART 1, HEARINGS BEFORE THE SUBCOMMITTEE ON OCEANOGRAPHY OF THE COMMITTEE ON MERCHANT MARINE AND FISHERIES, HOUSE OF REPRESENTATIVES, NINETH-SIXTH CONGRESS, MARCH 3, 1980. U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC. SERIAL NO. 96-28. PP. 1-37. (ERL,GB X165*).

THE SUBCOMMITTEE ON OCEANOGRAPHY MEETS TODAY TO RECEIVE SCIENTIFIC AND TECHNICAL TESTIMONY CONCERNING AVAILABLE RESEARCH ON THE NATURE AND COMPOSITION OF DRILL MUDS, DRILL CUTTINGS, AND FORMATION WATERS, AND THEIR SHORT- AND LONG -TERM EFFECTS ON THE ENVIRONMENT. THESE ARE MATERIALS EITHER USED IN, OR INCIDENTAL TO, OFFSHORE OIL AND GAS DRILLING. DRILLING MUDS ARE MIXTURES OF CLAYS, DIVERSE CHEMICALS, AND WATER WHICH ARE USED AS A LUBRICANT DURING OIL AND GAS OPERATIONS. THESE MUDS, WHICH VARY GREATLY IN COMPOSITION DEPENDING UPON THE SPECIFIC REQUIREMENTS OF AN INDIVIDUAL WELL, ARE ALSO PUMPED INTO THE OIL ELLS TO REINFORCE THE WALLS OF THE DRILLED HOLE, TO WEIGH THE DRILLING COLUMN WHICH HELPS PREVENT BLOW-OUTS, AND TO TRANSPORT CUTTINGS TO THE SURFACE. DRILL CUTTINGS ARE THOSE PIECES OF THE SEABED AND SUBSURFACE ROCK WHICH ARE DISPLACED OR IMPACTED BY THE DRILLING PROCESS. FORMATION WATERS ARE THE WATERS FOUND IN OFF-SHORE OIL AND GAS RESERVOIRS WHICH CONTAIN PETROLEUM, DISSOLVED MINERAL SALTS, AND TRACES OF HEAVY METALS. THESE WATERS ARE GENERALLY SEPARATED FROM THE OIL AND GAS AT THE SURFACE AND SIMPLY RETURNED TO THE WATER COLUMN FROM THE OIL RIG. ALL OF THESE MATERIALS CONTAIN POTENTIALLY HAZARDOUS SUBSTANCES WHICH COULD ADVERSELY AFFECT BIOLOGICAL POPULATIONS. THE EXTENT OF THAT HAZARD IS THE SUBJECT OF CONSIDERABLE DEBATE WITHIN THE SCIENTIFIC COMMUNITY WHICH INCLUDES GOVERNMENT, INDUSTRY, AND PRIVATE RESEARCHERS. IN ORDER TO MAKE INTELLIGENT ASSESSMENTS OF THE EFFECTS OF CERTAIN ACTIVITIES ON THE OCS, THE CONGRESS AND RELEVANT AGENCIES MUST HAVE ACCESS TO CONCLUSIVE SCIENTIFIC RESEARCH UPON WHICH TO BASE THESE ASSESSMENTS. IT IS FOR THIS REASON THAT THE SUBCOMMITTEE HAS REQUESTED WITNESSES FROM THE DEPARTMENT OF THE INTERIOR, THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND THE ENVIRONMENTAL PROTECTION AGENCY TO APPEAR BEFORE IT TO OFFER AN ASESSMENT OF CURRENT SCIENTIFIC KNOWLEDGE. REPRESENTATIVES OF THE DEPARTMENT OF THE INTERIOR HAVE STATED IN PAST TESTIMONY THAT THEY POSSESS A "SHELF FULL" OF STUDIES ON THESE MATERIALS, NONE OF WHICH INDICATES ANY ADVERSE LONG- OR SHORT-TERM ENVIRONMENTAL EFFECTS. HOWEVER, IN JULY OF LAST YEAR NOAA STATED THAT THE EVIDENCE ON THESE MATERIALS WAS "CONTRADICTORY AND CONTROVERSIAL" AND, IN FACT, RECOMMENDED BARGING OF THESE MATERIALS OFF GEORGES BANK TO AVOID UNREASONABLE RISK TO THE FISHERIES. THIS MEMBER HAS SEEN STUDIES WHICH INDICATE "NO EFFECT" AND OTHERS WHICH INDICATE "SIGNIFICANT EFFECTS." AT LEAST ONE INDUSTRY PUBLICATION WOULD INDICATE THAT WE DO NOT KNOW THE COMPOSITION OF THESE MATERIALS, LET ALONE THEIR EFFECTS. THUS, IN AN EFFORT TO ELIMINATE OUR CONFUSION--TO RESOLVE SOME OF THESE INCONGRUITIES--TODAY'S HEARING HAS BEEN CALLED.

POWELL, ERIC N., MARGARET KASSCHAU, EDWARD CHEN, MICHAEL KOENIG, AND JILL PECON. 1982. CHANGES IN THE FREE AMINO ACID POOL DURING ENVIRONMENTAL STRESS IN THE GILL TISSUE OF THE OYSTER, CRASSOSTREA VIRGINICA. COMP. BIOCHEM. PHYSIOL. A COMP. BIOCHEM. 71A(4):591-598. (ERL,GB X203*).

1. OYSTERS WERE EXPOSED FOR 2- AND 5-DAY PERIODS TO INCREASED SALINITY (26%-38%), ANOXIA TURBIDITY AND DRILLING EFFLUENTS. 2. AFTER TWO DAYS, THE FAA POOL IN THE GILL TISSUE OF OYSTERS EXPOSED TO 38% SALINITY HAD ELEVATED GLYCINE, ALANINE AND B-ALANINE LEVELS; OYSTERS EXPOSED TO ANOXIA SHOWED ELEVATED GLYCINE AND ALANINE AND DECREASED ASPARTIC ACID LEVELS. 3. AFTER 2 DAYS, BOTH OYSTERS EXPOSED TO TURBIDITY AND TO DRILLING EFFLUENTS HAD INCREASED CYSTEIC ACID LEVELS. GLUTAMIC ACID AND ALANINE LEVELS WERE ALSO ELEVATED IN OYSTERS EXPOSED TO DRILLING EFFLUENTS. 4. AFTER 5 DAYS, GLYCINE, ALANINE AND B-ALANINE REMAINED ABOVE CONTROL LEVELS IN OYSTERS EXPOSED TO INCREASED SALINITY WHEREAS IN THOSE EXPOSED TO ANOXIA, TURBIDITY AND DRILLING EFFLUENTS, A SIGNIFICANT DECREASE IN MOST AMINO ACIDS OCCURRED WITH THE TOTAL FAA POOL DECREASING BY 50%. 5. THE FAA POOL'S RESPONSE WAS UNIQUE FOR EACH STRESS STUDIED SUGGESTING THAT THE FAA POOL MAY PROVE TO BE A USEFUL DIAGNOSTIC TOOL FOR DETERMINING A POSTERIORI THE CAUSATIVE AGENT RESPONSIBLE FOR A GIVEN STRESS RESPONSE.

POWELL, E.N., S.J. CONNOR, J.J. KENDALL, C.E. ZASTROW, AND T.J. BRIGHT. 1984. RECOVERY BY THE CORAL ACROPORA CERVICORNIS AFTER DRILLING MUD EXPOSURE. THE FREE AMINO ACID POOL. ARCH. ENVIRON. CONTAM. TOXICOL. 13(2):243-258. (ERL,GB X462*).

CORALS WERE EXPOSED TO DRILLING MUD FOR 24 HR AND THEN ALLOWED TO RECOVER FOR 48 HR IN CLEAN SEAWATER. DEPENDING ON THE CONCENTRATION AND THE MUD USED, EXPOSURE PRODUCED EITHER AN INCREASE OR DECREASE IN FREE AMINO ACID (FAA) POOL SIZE. ASPARTATE WAS AFFECTED TO A GREATER DEGREE THAN OTHER AMINO ACIDS. NO CLEAR INSTANCE OF RECOVERY COULD BE ASCERTAINED AFTER 48 HR IN CLEAN SEAWATER. IN SEVERAL CASES, CORALS, APPARENTLY UNAFFECTED BY A 24 HR EXPOSURE, NEVERTHELESS SUFFERED SIGNIFICANT CHANGES IN THE FAA POOL DURING THE 48 HR RECOVERY PERIOD. THUS, THE DEGREE OF TOXICITY OF THE DRILLING MUD COULD NOT BE ACCURATELY PREDICTED FROM THE 24 HR EXPOSURE DATA. IN MANY CASES, THE CHOICE OF NORMALIZING PARAMETER DETERMINED WHETHER TWO SETS OF DATA WERE SIGNIFICANTLY DIFFERENT OR NOT ACCURATE EFFECTS ASSESSMENT DEPENDS ON A COMPARISON OF NORMALIZATION TO CONFIRM STATISTICAL RESULTS.

RAO, K. RANGA, AND DANIEL G. DOUGHTIE. IN PRESS. HISTOPATHOLOGICAL CHANGES IN GRASS SHRIMP EXPOSED TO CHROMIUM, PENTACHLOROPHENOL, AND DITHIOCARBAMATES. IN: RESPONSES OF MARINE ANIMALS TO POLLUTANTS. J. HEATH AND J. STEGEMAN, EDITORS, ELSEVIER/APPLIED SCIENCE PUBLISHERS. (ERL,GB X435).

THIS REPORT DEALS WITH THE HISTOPATHOLOGICAL/ULTRASTRUCTURAL CHANGES IN VARIOUS TISSUES OF GRASS SHRIMP PALAEMONETES PUGIO) EXPOSED TO HEXAVALENT AQUATREAT DNM-30 (15% SODIUM DIMETHYL DITHIOCARBAMATE PLUS 15% DISODIUM ETHYLENE BISDITHIOCARBAMATE) AND BUSAN-85 (50% POTASSIUM DIMETHYL DITHIOCARBAMATE). THE PATHOLOGICAL ALTERATIONS INDUCED BY DITHIOCARBAMATES AND PCP WERE MOST SEVERE AND FIRST EVIDENT IN THE GILLS OF THE BIOCIDES TESTED, THE DITHIOCARBAMATES CAUSED THE MOST EXTENSIVE BRANCHIAL DAMAGE--THE SO CALLED BLACK GILL SYNDROME, INVOLVING EARLY MELANIZATION AND EVENTUAL LAMELLAR TRUNCATION. HEXAVALENT CHROMIUM, ON THE OTHER HAND, DID NOT INDUCE MARKED CHANGES IN THE GILLS, BUT IT CAUSED INVASIVE MELANIZED CUTICULAR LESIONS (PARTICULARLY AT THE ARTICULATIONS OF THE PEREIOPODS, PLEOPODS, AND ABDOMINAL SEGMENTS). ADDITIONALLY CHROMIUM CAUSED APPARENT LABYRINTH HYPOACTIVITY IN THE ANTENNAL GLANDS, WHEREAS THE DITHIOCARBAMATES SEEMED TO INDUCE LABYRINTH HYPERACTIVITY. HEPATOPANCREATIC HISTOPATHOLOGY WAS MORE SEVERE IN SHRIMP EXPOSED TO CHROMIUM AND PCP THAN IN DITHIOCARBAMATE-EXPOSED SHRIMP. THE APPARENT MITOTIC ACTIVITY IN THE HEPATOPANCREAS WAS INCREASED IN AQUATREAT-EXPOSED SHRIMP AND SUPPRESSED IN CHROMIUM-EXPOSED SHRIMP; MANY MITOTIC FIGURES IN THE LATTER CASE WERE ABNORMAL. ALL FOUR COMPOUNDS CAUSED VARYING DEGREES OF MIDGUT EPITHELIAL HYPERTROPHY, CYTOPLASMIC VACUOLIZATION, AND DIMINUTION OF BASAL TUBULAR ENDOPLASMIC RETICULUM, BUT ONLY PCP CAUSED WIDESPREAD RUPTURE OF MIDGUT EPTITHELIAL CELL APICES. ADDITIONAL NOTABLE ULTRASTRUCTURAL ANOMALIES INCLUDED: MITOCHONDRIAL COMPARTMENTALIZATION IN PCP-EXPOSED SHRIMP; MITOCHONDRIAL FUSION IN DITHIOCARBAMATE-EXPOSED SHRIMP. THESE PATHOLOGICAL CHANGES POINT TO DIFFERENCES IN THE MECHANISMS OF POLLUTANT TOXICITY AND INDICATE THEIR POTENTIAL USE IN THE BIOLOGICAL MONITORING OF AQUATIC POLLUTANTS.

RAO, K. RANGA, PHILIP J. CONKLIN, AND ANITA C. BRANNON. 1978. INHIBITION OF LIMB REGENERATION IN THE GRASS SHRIMP, PALAEMONETES PUGIO, BY SODIUM PENTACHLOROPHENATE. IN: PENTACHLOROPHENOL: CHEMISTRY, PHARMACOLOGY, AND ENVIRONMENTAL TOXICOLOGY. K. RANGA RAO, EDITOR, PLENUM PRESS, NEW YORK, NY. PP. 193-203. (ERL,GB X116*).

THE INITIATION AND PROGRESS OF REGENERATION FOLLOWING THE REMOVAL OF THE LEFT FIFTH PEREIOPOD WERE STUDIED USING THE GRASS SHRIMP, PALAEMONETES PUGIO. THE REGENERATION PATTERNS OF 400 SHRIMP SUBJECTED TO VARIOUS TREATMENTS REVEALED THAT SODIUM PENTACHLOROPHENATE (NA-PCP) AFFECTS THE INITIATION AND PROGRESS OF LIMB REGENERATION. DEPENDING ON THE CONCENTRATION USED, NA-PCP CAUSED EITHER A COMPLETE INHIBITION OF REGENERATION, A DELAY OF INITIATION OF LIMB BUD DEVELOPMENT, OR A REDUCTION OF LIMB BUD GROWTH WITHOUT ALTERING THE INTERMOLT DURATION. BY COMPARING THE REGENERATION INDICES (R VALUES) OF CONTROL AND EXPERIMENTAL SHRIMP NOTED ON SPECIFIED DAYS PRECEDING ECDYSIS AND ON THE DAY FOLLOWING ECDYSIS IT WAS POSSIBLE TO DETERMINE THE EXTENT (%) OF INHIBITION OF REGENERATION IN SHRIMP EXPOSED TO NA-PCP. EC50 VALUES WERE COMPUTED USING PROBIT ANALYSIS. FOR EXAMPLE, THE R VALUES OF SHRIMP NINE DAYS AFTER LIMB REMOVAL YIELDED THE FOLLOWING EC50 VALUES WITH 95% CONFIDENCE INTERVALS SHOWN IN PARENTHESIS: UNFED SHRIMP, 0.473 PPM NA-PCP (0.306-0.670); FED SHRIMP, 0.565 PPM (0.452-0.706). THE EC50 VALUES BASED ON POSTECDYSIAL R VALUES WERE: UNFED SHRIMP, 0.615 PPM NA-PCP (0.451-0.852); FED SHRIMP, 0.637 PPM (0.485-0.850). THE INHIBITORY EFFECTS OF NA-PCP WERE MORE PRONOUNCED ON THE INITIAL PHASES OF LIMB REGENERATION (INVOLVING WOUND HEALING, CELL DIVISION AND DEDIFFERENTIATION) THAN ON THE LATER PHASES OF REGENERATION (INVOLVING FURTHER DIFFERENTIATION AND CELLULAR ENLARGEMENT). CRUSTACEAN LIMB REGENERATION CAN BE USED AS A SENSITIVE BIOASSAY FOR STUDYING THE EFFECTS OF CHEMICAL POLLUTANTS.

RAO, K. RANGA, FERRIS R. FOX, PHILIP J. CONKLIN, ANGELA C. CANTELMO, AND ANITA C. BRANNON. 1979. PHYSIOLOGICAL AND BIOCHEMICAL INVESTIGATIONS OF THE TOXICITY OF PENTACHLOROPHENOL TO CRUSTACEANS. IN: MARINE POLLUTION: FUNCTIONAL RESPONSES. W.B. VERNBERG, A. CALABRESE, F. THURBERG, AND F.J. VERNBERG, EDITORS, ACADEMIC PRESS, NEW YORK, NY. PP. 307-339. (ERL,GB X117*).

A SERIES OF PHYSIOLOGICAL AND BIOCHEMICAL INVESTIGATIONS TO DETERMINE THE TOXICITY OF PENTACHLOROPHENOL TO CRUSTACEANS ARE DESCRIBED. THE STUDIES FOCUS ON: (1) THE TOXICITY OF NA-PCP TO GRASS SHRIMP AT DIFFERENT STAGES OF THE MOLT CYCLE; (2) THE EFFECTS OF NA-PCP ON LIMB REGENERATION IN GRASS SHRIMP, (3) THE EFFECTS OF NA-PCP AND 2,4-DINITROPHENOL (DNP) ON OXYGEN CONSUMPTION BY GRASS SHRIMP AND TISSUES FROM BLUE CRABS, AND (4) THE EFFECTS OF NA-PCP AND DNP ON BLUE CRAB HEPATOPANCREATIC ENZYMES. TESTS WITH DNP, ALSO A KNOWN UNCOUPLER, PERMITTED A COMPARISON OF THE EFFECTS OF BOTH PHENOLS.

RAO, K. RANGA, FERRIS R. FOX, PHILIP J. CONKLIN, AND ANGELA C. CANTELMO. 1981. COMPARATIVE TOXICOLOGY AND PHARMACOLOGY OF CHLOROPHENOLS: STUDIES ON THE GRASS SHRIMP, PALAEMONETES PUGIO. IN: BIOLOGICAL MONITORING OF MARINE POLLUTION. J. VERNBERG, F. THURBERG, A. CALABRESE, AND W. VERNBERG, EDITORS, ACADEMIC PRESS, INC., NEW YORK. PP. 37-72. (ERL,GB X235*).

EXPERIMENTS WITH THE GRASS SHRIMP, PALAEMONETES PUGIO, TO ASSESS THE TOXICITY OF SEVERAL CHLOROPHENOLS: 2,4-DICHLOROPHENOL, 2,4,5-TRICHLOROPHENOL, 2,4,6-TRICHLOROPHENOL, 2,3,4,5-TETRACHLOROPHENOL, 2,3,4,6-TETRACHLOROPHENOL, 2,3,5,6-TETRACHLOROPHENOL, AND PENTACHLOROPHENOL ARE DESCRIBED. AUTHORS REPORT A CYCLIC VARIATION IN GRASS SHRIMP SUSCEPTIBILITY TO VARIOUS CHLOROPHENOLS IN RELATION TO THE MOLT CYCLE. WITH THE EXCEPTION OF 2,4-DICHLOROPHENOL, THE VARIOUS CHLOROPHENOLS WERE MORE TOXIC TO MOLTING SHRIMP THAN TO NON-MOLTING SHRIMP IS DUE TO AN INCREASED BIOACCUMULATION OF THESE DURING THE PERIOD SHORTLY AFTER MOLTING.

RAO, K. RANGA, DANIEL G. DOUGHTIE, AND PHILIP J. CONKLIN. 1982. PHYSIOLOGICAL AND HISTOPATHOLOGICAL EVALUATION OF DITHIOCARBAMATE TOXICITY TO THE GRASS SHRIMP, PALAEMONETES PUGIO. IN: PHYSIOLOGICAL MECHANISMS OF MARINE POLLUTANT TOXICITY. W.B. VERNBERG, A. CALABRESE, AND F.P. THURBERG, EDITORS, ACADEMIC PRESS, NEW YORK. PP. 413-445. (ERL,GB X369*). AVAIL. FROM NTIS, SPRINGFIELD, VA: PB83-247205.

TOXICITY TESTS ON AQUATREAT DNM-30 (96 H LC50: 127 PPB) AND BUSAN 85 (96 H LC50: 49 PPB) REVEALED THAT DITHIOCARBAMATES ARE HIGHLY TOXIC TO MOLTING GRASS SHRIMP (PALAEMONETES PUGIO). THE RESULTS OF THESE TESTS, WHEN COUPLED WITH OTHER REPORTS ON DITHIOCARBAMATE TOXICITY, SUGGEST THAT CRUSTACEANS ARE MORE SENSITIVE TO DITHIOCARBAMATES THAN ARE FISH. IN LIMB REGENERATION STUDIES, BOTH OF THE DITHIOCARBAMATE FORMULATIONS CAUSED A DOSE-RELATED INHIBITION OF REGENERATIVE LIMB GROWTH IN GRASS SHRIMP; THE D 4 (96 H) EC50S FOR INHIBITION OF REGENERATIVE LIMB GROWTH WERE LOWER THAN THE 96 H LC50 VALUES. SINCE THE NUMBER OF DAYS TO MOLTING WAS NOT SIGNIFICANTLY ALTERED BY AQUATREAT OR BUSAN-EXPOSURE, DITHIOCARBAMATES APPEAR TO PRIMARILY EXERT THEIR EFFECT DIRECTLY ON THE DEVELOPING LIMB BUD TISSUE RATHER THAN THROUGH THE NEUROENDOCRINE SYSTEM. DURING THE COURSE OF EXPOSURE TO THE DITHIOCARBAMATES, SOME OF THE SHRIMP DEVELOPED GROSS ABNORMALITIES IN GILL MORPHOLOGY. RESPIRATION STUDIES REVEALED THAT AQUATREAT AND BUSAN-EXPOSED GRASS SHRIMP EXHIBITED LOWER RATES OF OXYGEN CONSUMPTION THAN DID CONTROL SHRIMP. HISTOLOGICAL AND ULTRASTRUCTURAL EXAMINATIONS REVEALED A GRADATION OF PATHOLOGICAL RESPONSES IN THE CARBAMATE-EXPOSED GILLS--INCLUDING A MASSIVE INFLUX OF HEMOXYTES INTO DEGENERATING GILL LAMELLAE, THE FORMATION OF PRESUMABLY MELANIZED PLUGS INTO LAMELLAR APICES, AND THE SLOUGHING OF THESE PLUGS AND SURROUNDING CUTICLE AT THE ECDYSIS--LEADING TO LAMELLAR TRUNCATION AND TO DEGENERATION OF ENTIRE PLEUROBRANCHIAL GILL PROCESSES. THE OBSERVED DEFENSIVE RESPONSE OF GRANULAR HEMOCYTES TO DITHIOCARBAMATES IS COMPARABLE TO SOME OF THE PREVIOUSLY DESCRIBED WOUND HEALING RESPONSES IN OTHER CRUSTACEANS.

RHOADS, DONALD C., AND LARRY F. BOYER. 1982. EFFECTS OF MARINE BENTHOS ON PHYSICAL PROPERTIES OF SEDIMENTS: A SUCCESSIONAL PERSPECTIVE. IN: ANIMAL-SEDIMENT RELATIONS. P.L. MCCALL AND M.J.S. TEVESZ, EDITORS, PLENUM PUBLISHING CORPORATION, NEW YORK. PP. 3-52. (ERL,GB 479*).

THIS CHAPTER FOCUSES ON PHYSICAL ORGANISM-SEDIMENT RELATIONS THAT ARE OF POTENTIAL VALUE IN PREDICTING THE PHYSICAL PROPERTIES OF SEDIMENTS AND THE TRANSPORT FATES OF FINE-GRAINED SEDIMENTS AND THEIR ASSOCIATED CONTAMINANTS. GENERALIZATIONS ARE MADE ABOUT HOW EARLY AND LATE SUCCESSIONAL STAGES INFLUENCE THE PHYSICAL PROPERTIES OF SEDIMENTS--SOME OF THE CAUSE-AND-EFFECT RELATIONSHIPS ARE WELL KNOWN, WHILE OTHERS REMAIN SPECULATIVE. A FEW PROMISING TECHNIQUES AND APPROACHES FOR FUTURE WORK ARE DISCUSSED.

RUBINSTEIN, NORMAN I., REBECCA RIGBY, AND CHARLES N. D'ASARO. 1980. ACUTE AND SUBLETHAL EFFECTS OF WHOLE USED DRILLING FLUIDS ON REPRESENTATIVE ESTUARINE ORGANISMS. IN: SYMPOSIUM: RESEARCH ON ENVIRONMENTAL FATE AND EFFECTS OF DRILLING FLUIDS AND CUTTINGS, JAN. 21-24, 1980, LAKE BUENA VISTA, FL., VOL. 2. AMERICAN PETROLEUM INSTITUTE, WASHINGTON, DC. PP. 828-846. (ERL,GB 160*).

A LONG-TERM (100 DAYS) MULTISPECIES TOXICITY TEST WAS CONDUCTED TO ELUCIDATE BIOLOGICAL EFFECTS OF DRILLING FLUIDS ON REPRESENTATIVE ESTUARINE ORGANISMS AND DEVELOPING BENTHIC COMMUNITIES. ORGANISMS SELECTED FOR STUDY WERE: THE MYSID SHRIMP, MYSIDOPSIS BAHIA, A WATER COLUMN CRUSTACEAN, THE OYSTER, CRASSOSTREA VIRGINICA, AN EPIBENTHIC MOLLUSK, AND A DEPOSIT FEEDING POLYCHAETE, ARENICOLA CRISTATA. RESULTS INDICATE THAT THE DRILLING FLUIDS TESTED WERE MODERATELY TOXIC TO MYSIDS AT 30 TO 100 PPM. OYSTER GROWTH WAS ALSO SIGNIFICANTLY INHIBITED AT THESE CONCENTRATIONS. LUGWORM SURVIVAL IN ALL THREE CONCENTRATIONS WAS SIGNIFICANTLY REDUCED. FINALLY, EXCLUSION OF EARLY COLONIZING MOLLUSKS WAS OBSERVED IN AQUARIA CONTAINING 100 PPM DRILLING FLUIDS.

SCHATTEN, GERALD, CALVIN SIMERLY, AND HEIDE SCHATTEN. IN PRESS. EFFECTS OF BARIUM SULFATE ON SEA URCHIN FERTILIZATION AND EARLY DEVELOPMENT. IN: WASTES IN THE OCEAN, VOLUME 3. JOHN WILEY & SONS, INC., NEW YORK, NY. (ERL,GB X427).

FERTILIZATION AND DEVELOPMENT OF SEA URCHINS OFFER AN UNRIVALED SYSTEM TO STUDY THE CELLULAR CONSEQUENCES OF EXOGENOUS IONS. AT FERTILIZATION, A VARIETY OF EVENTS OCCUR, INCLUDING THE ACROSOME REACTION OF THE SPERM, THE CORTICAL REACTION OF THE EGG, SPERM INCORPORATION, THE UNION OF THE SPERM AND EGG NUCLEI WITHIN THE EGG CYTOPLASM, BIOELECTRIC CHANGES, THE ESTABLISHMENT OF THE BLOCK TO POLYSPERMY AND THE ACTIVATION OF THE METABOLISM OF THE FERTILIZED EGG. THESE EVENTS REQUIRE A COMPLEX REPERTOIRE OF ENZYMATIC AND STRUCTURAL CHANGES IN CELLULAR BEHAVIOR AND ARE REGULATED BY IONIC FLUXES, PARTICULARLY BY CHANGES IN INTRACELLULAR CALCIUM CONCENTRATION. BARIUM, A DIVALENT CATION, MIGHT BE EXPECTED TO MIMIC CALCIUM IN THIS MARINE SYSTEM AND TO INTERFERE WITH THE CELLULAR AND DEVELOPMENTAL EVENTS NORMALLY REGULATED BY CALCIUM FLUXES. GAMETES FROM THE GULF COAST SEA URCHINS LYTECHINUS VARIEGATUS AND ARBACIA PUNCTULATA WERE STUDIED BY LIGHT, ELECTRON AND TIME-LASPE VIDEO MICROSCOPY TO EVALUATE THE INTERFERENCE BY BARIUM SULFATE WITH NORMAL FERTILIZATION AND DEVELOPMENT. IN BARIUM SULFATE CONCENTRATIONS ABOVE 1 MILLIMOLAR, ALL THE NORMAL EVENTS AT FERTILIZATION WERE DRASTICALLY REDUCED; AT 10 MILLIMOLAR BARIUM SULFATE, ZERO PERCENT FERTILIZATION AND DEVELOPMENT WERE NOTED. THESE RESULTS INDICATE THAT HIGH CONCENTRATIONS (GREATER THAN 1 MMOL) OF BARIUM SULFATE CAN INTERFERE WITH NORMAL FERTILIZATION AND DEVELOPMENT OF SEA URCHINS AT SITES THAT ARE USUALLY REGULATED BY CALCIUM IONS.

SCIENCE APPLICATIONS, INC., LA JOLLA, CA. 1984. DRILL MUD ASSESSMENT CHEMICAL ANALYSIS REFERENCE VOLUME. EPA-600/3-84-048, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 265P. AVAIL. FROM NTIS, SPRINGFIELD, VA: PB84-170000.

THIS REPORT PRESENTS CONCENTRATIONS OF SPECIFIC METALS AND HYDROCARBONS IN ELEVEN DRILLING FLUIDS (MUDS) TAKEN FROM OPERATING GAS AND OIL RIGS IN THE GULF OF MEXICO. EACH DRILLING FLUID WAS ANALYZED CHEMICALLY FOR HEAVY METAL AND HYDROCARBON CONTENT IN THREE DISTINCT PHASES: (1) THE BULK OR WHOLE MUD, (2) A SUSPENDED PHASE DERIVED FROM THE BULK MUD SAMPLE, AND (3) A "DISSOLVED" OR LIQUID PHASE. ALIQUOTS OF BULK MUDS WERE REMOVED FOR BARIUM ANALYSES BY INSTRUMENTAL NEUTRON ACTIVATION AND FOR ANALYSIS FOR IRON, ALUMINUM, LEAD, ZINC, CADMIUM, COPPER, STRONTIUM, AND CALCIUM BY ATOMIC ABSORPTION ANALYSIS. ANALYSIS OF THE SUSPENDED PARTICULATE AND LIQUID PHASES WAS SIMILAR. THE AROMATIC AND ALIPHATIC CONTENT OF THE THREE PHASES WERE DETERMINED BY EXTRACTION AND THE FRACTIONATION BY COLUMN CHROMATOGRAPHY. THE ANALYSIS FOR EACH OF THE 11 DRILLING FLUIDS IS PRESENTED IN FOUR PARTS: A. DRILLING FLUID CONCENTRATIONS, B. WHOLE DRILLING FLUID ORGANIC CONCENTRATIONS, C. PARTICULATE PHASE ORGANIC CONCENTRATIONS, D. "DISSOLVED" PHASE ORGANIC CONCENTRATIONS.

SMITH, GLEN A., JANET S. NICKELS, RONALD J. BOBBIE, NORMAN L. RICHARDS, AND DAVID C. WHITE. 1982. EFFECTS OF OIL AND GAS WELL-DRILLING FLUIDS ON THE BIOMASS AND COMMUNITY STRUCTURE OF MICROBIOTA THAT COLONIZE SANDS IN RUNNING SEAWATER. ARCH. ENVIRON. CONTAM. TOXICOL. 11(1):17-23. (ERL,GB X303*).

WELL-DRILLING FLUID AND A NUMBER OF THE KNOWN COMPONENTS (BARITE, CLAY, ALDACIDE, SURFLO, AND DOWICIDE, WERE TESTED FOR EFFECTS ON THE BIOMASS AND COMMUNITY STRUCTURE OF THE MICROBIOTA THAT COLONIZE MARINE SANDS EXPOSED FOR EIGHT WEEKS TO RUNNING AMBIENT SEAWATER. SHADING THE MICROBIOTA FROM LIGHT DEPRESSED THE MICROFLORA WITHOUT A SIGNIFICANT EFFECT ON THE BIOMASS, WHILE WELL-DRILLING FLUIDS LAYERED ON THE SURFACE OR MIXED WITH THE SAND SIGNIFICANTLY INCREASED A COMPONENT OF THE BACTERIA AND THE MICROFAUNA AS REFLECTED IN CHANGES IN THE FATTY ACID COMPOSITION. THERE WERE SOME SHADING EFFECTS FROM THE SURFACE LAYERING OF WELL-DRILLING FLUIDS AS REFLECTED IN THE FATTY ACIDS FROM THE MICROFLORA WHEN COMPARED TO THE SANDS MIXED WITH WELL-DRILLING FLUIDS. BARITE HAD ESSENTIALLY NO EFFECT ON THE BIOMASS OR COMMUNITY STRUCTURE WHILE CLAYS INCREASED NEARLY ALL OF THE BIOMASS INDICATORS FOR THE BACTERIA AS WELL AS THE MICROFAUNA; THE CLAY OVERLAY MIRRORS THE EFFECT OF THE DRILLING FLUIDS. ALDACIDE SHIFTED THE BACTERIAL COMPOSITION, DEPRESSING THE PROPORTIONS OF MICROBES CONTAINING THE CYCLOPROPANE FATTY ACIDS AND THE ANAEROBIC PATHWAYS OF DESATURATION. CONCENTRATIONS OF 1 AND 15 UG/L INCREASED THE BACTERIAL BIOMASS AS REFLECTED IN THE TOTAL LIPID (16:0) AND EXTRACTABLE LIPID PHOSPHATE COUPLED WITH A DECREASE IN THE TOTAL MICROEUKARYOTES. SURFLO INCREASED IN THE BIOMASS AND SHIFTED THE BACTERIAL COMMUNITY STRUCTURE AT CONCENTRATIONS BETWEEN 4 AND 800 UG/L. THE LOWEST LEVEL ALSO STIMULATED THE MICROFAUNA. DOWICIDE AT 100 UG/L INCREASED THE BACTERIA FORMING CISVACCENIC ACID AND THE MICROFAUNA SIMILAR TO LOW CONCENTRATIONS OF SURFLO.

SZMANT-FROELICH, A., V. JOHNSON, T. HOEHN, J. BATTEY, G.J. SMITH, E. FLEISCHMANN, J. PORTER, AND D. DALLMEYER. 1982. PHYSIOLOGICAL EFFECTS OF OIL-DRILLING MUDS ON THE CARIBBEAN CORAL MONTASTREA ANNULARIS. IN: REEF AND MAN: PROCEEDINGS OF THE FOURTH INTERNATIONAL CORAL REEF SYMPOSIUM, MANILA, PHILIPPINES, 18-22, MAY, 1981. EDGARDO D. GOMEZ, ET AL., EDITOR, MARINE SCIENCES CENTER, UNIVERSITY OF THE PHILIPPINES, QUEZON CITY, PHILIPPINES. PP. 163-168. (ERL,GB X307*).

THE EFFECT OF CHRONIC EXPOSURE TO DRILLING MUDS ON THE REEF CORAL MONTASTREA ANNULARIS WAS INVESTIGATED. COLONIES WERE EXPOSED FOR 6 WEEKS TO CONCENTRATIONS OF 0, 1, 10 AND 100 PPM DRILLLING MUD IN A FLOW-THRU SEAWATER SYSTEM. WEEKLY MEASUREMENTS WERE MADE OF CORAL RESPIRATION, PHOTOSYNTHESIS, CALCIFICATION AND NH4 AND NO3 UPTAKE RATES. CALCIFICATION AND RESPIRATION RATES OF CORALS EXPOSED TO 100 PPM DRILLING MUD DECREASED BY 53% AND 25% RESPECTIVELY AFTER 4 WEEKS OF EXPOSURE AND BY 84% AND 40% AFTER 6 WEEKS. GROSS PHOTOSYNTHESIS WAS REDUCED BY 26% AFTER 5 WEEKS. NO3 UPTAKE RATES DECREASED BY 42% AND 48% AFTER 4 AND 6 WEEKS WHILE NH4 UPTAKE DECREASED BY 32% AND 49% AFTER 5 AND 6 WEEKS OF EXPOSURE. SEVERAL OF THE 100 PPM CORALS DIED BEFORE THE END OF THE EXPERIMENT, WHILE NONE OF THE OTHER CORALS DIED. CALCIFICATION AND RESPIRATION RATES OF 10 PPM CORALS WERE LOWER BUT NOT SIGNIFICANTLY DIFFERENT FROM THOSE OF CONTROLS. BRINE SHRIMP EXTRACT ELICITED NORMAL FEEDING RESPONSES FROM CONTROL, 1 PPM AND 10 PPM CORALS BUT NOT FROM THE 100 PPM CORALS AFTER 6 WEEKS OF EXPOSURE TO DRILLING MUD. THE LATTER GROUP STILL DID NOT RESPOND TO THE EXTRACT AFTER A 1-WEEK RECOVERY PERIOD IN CLEAN SEAWATER.

SZMANT-FROELICH, ALINA. 1983. PHYSIOLOGICAL EFFECTS OF DRILLING MUDS ON REEF CORALS. EPA-600/3-83-013, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, GULF BREEZE, FL. 54P.

PIECES OF CORAL FROM TWO SPECIES, MONTASTREA ANNULARIS AND ACROPORA CERVICORNIS, WERE EXPOSED IN THE LABORATORY TO CONCENTRATIONS OF 0, 1, 10, AND 100 PPM DRILLING MUD FOR PERIODS TWO DAYS TO SEVEN WEEKS. SEVERAL PHYSIOLOGICAL FUNCTIONS OF THE CORAL ANIMAL (CALCIFICATION RATE, RESPIRATION RATE) AND OF THEIR ZOOXANTHELLAE (PHOTOSYNTHESIS RATE, NUTRIENT UPTAKE RATE) WERE MONITORED AT REGULAR INTERVALS DURING THE EXPOSURE PERIODS. IN ADDITION, BIOMASS PARAMETERS (TISSUE NITROGEN, ZOOXANTHELLAE CELL DENSITY, CHLOROPHYLL CONTENT) WERE MEASURED AT TWO-WEEK INTERVALS FOR THE LONGER EXPOSURE EXPERIMENT, AND AT THE END OF EACH EXPERIMENT FOR THE SHORTER EXPOSURES. INITIAL LONG-TERM EXPOSURES OF PIECES OF MONTASTREA ANNULARIS TO A SERIES OF DRILL MUDS (DESIGNATED JX-2 THROUGH JX-7) COLLECTED FROM A JAY OIL-FIELD WELL SHOWED A SIGNIFICANT DETRIMENTAL EFFECT ON CALCIFICATION, RESPIRATION, AND NO(3) UPTAKE RATES DURING THE FOURTH WEEK OF EXPOSURE TO 100 PPM DRILL MUD. PHOTOSYNTHESIS AND NH(4) UPTAKE RATES WERE AFFECTED ALSO DURING THE FIFTH WEEK OF EXPOSURE. NORMAL FEEDING BEHAVIOR WAS ABSENT FROM THESE CORALS WHEN TESTED DURING THE SIXTH AND SEVENTH WEEKS OF EXPOSURE. SEVERAL 100 PPM CORALS DIED DURING THE FIFTH AND SIXTH WEEKS.

TAGATZ, MARLIN E., JOEL M. IVEY, JAMES C. MOORE, AND MICHAEL TOBIA. 1977. EFFECTS OF PENTACHLOROPHENOL ON THE DEVELOPMENT OF ESTUARINE COMMUNITIES. J. TOXICOL. ENVIRON. HEALTH. 3(3):501-506. (ERL,GB 310*).
AVAIL. FROM NTIS, SPRINGFIELD, VA: PB-277 154.

PENTACHLOROPHENOL AFFECTED THE COMPOSITION OF COMMUNITIES OF ESTUARINE ORGANISMS DEVELOPED IN SAND FROM PLANKTONIC LARVAE IN ESTUARINE WATER THAT FLOWED THROUGH TEN CONTROL AQUARIA AND TEN AQUARIA PER EXPOSURE CONCENTRATION AVERAGING 7, 76, OR 622 MG/LITER. ANNELIDS, ARTHROPODS, AND MOLLUSKS WERE THE NUMERICALLY DOMINANT PHYLA WHEN ANIMALS WERE COLLECTED IN A 1-MM-MESH SIEVE AFTER 9 WK OF EXPOSURE. MOLLUSKS WERE MARKEDLY FEWER AT 7 MG/LITER; ANNELIDS AND ARTHROPODS AT 76 MG/LITER. ALMOST NO ANIMALS OCCURRED AT 622 MG/LITER. THE TOTAL NUMBERS OF INDIVIDUALS AND SPECIES WERE SIGNIFICANTLY LESS (A=0.01) IN AQUARIA EXPOSED TO 76 MG/LITER THAN IN THOSE UNEXPOSED OR EXPOSED TO 7 MG/LITER.

TAGATZ, MARLIN E., AND MICHAEL TOBIA. 1978. EFFECT OF BARITE (BASO4) ON DEVELOPMENT OF ESTUARINE COMMUNITIES. ESTUARINE COASTAL MAR. SCI. 7(4):401-407. (ERL,GB 340).

BARITE (BASO4), THE PRIMARY COMPONENT OF OIL DRILLING MUDS, AFFECTED THE COMPOSITION OF ESTUARINE COMMUNITIES DEVELOPED FROM PLANKTONIC LARVAE IN AQUARIA CONTAINING SAND AND FLOWING ESTUARINE WATER. AQUARIA CONTAINED: SAND ONLY; A MIXTURE (BY VOLUME) OF 1 PART BARITE AND 10 PARTS SAND; 1 PART BARITE, AND 3 PARTS SAND; OR SAND COVERED BY 0.5 CM BARITE. FOR ALL ENVIRONMENTS, ANNELIDS AND MOLLUSKS WERE THE NUMERICALLY DOMINANT PHYLA COLLECTED IN A 1-MM-MESH SIEVE AFTER 10 WEEKS EXPOSURE; A TOTAL OF 3020 ANIMALS, REPRESENTING 59 SPECIES, WAS COLLECTED. SIGNIFICANTLY FEWER ANIMALS AND SPECIES (A=0.01) DEVELOPED IN AQUARIA SAND COVERED BY BARITE THAN IN AQUARIA UNEXPOSED OR EXPOSED TO 1 BARITE:10 SAND. NUMBER OF ANIMALS IN AQUARIA CONTAINING 1 BARITE:3 SAND ALSO DIFFERED (A=0.05) FROM THAT IN CONTROL AQUARIA. ANNELIDS WERE PARTICULARLY AFFECTED AND SIGNIFICANTLY FEWER (A=0.01) WERE FOUND IN ALL TREATMENTS THAN IN THE CONTROL. MOLLUSKS DECREASED MARKEDLY IN NUMBER ONLY IN BARITE-COVERED AQUARIA. BARITE, HOWEVER, DID NOT IMPEDE GROWTH (AS HEIGHT) OF THE ABUNDANT CLAM, LAEVICARDIUM MORTONI, OR DECREASE ABUNDANCE OF SIX OTHER PHYLA. OUR DATA INDICATE THAT LARGE QUANTITIES OF THIS COMPOUND, AS DISCHARGED IN OFFSHORE OIL DRILLING, POSSIBLY COULD ADVERSELY AFFECT THE COLONIZATION OF BENTHIC ANIMALS.

TAGATZ, M.E., J.M. IVEY, H.K. LEHMAN, AND J.L. OGLESBY. 1978. EFFECTS OF A LIGNOSULFONATE-TYPE DRILLING MUD ON DEVELOPMENT OF EXPERIMENTAL ESTUARINE MACROBENTHIC COMMUNITIES. NORTHEAST GULF SCI. 2(1):35-42. (ERL,GB 370).

DRILLING MUD, AS USED IN EXPLORATORY DRILLING FOR OIL OFFSHORE, AFFECTED THE COMPOSITION OF ESTUARINE COMMUNITIES THAT DEVELOPED FROM PLANKTONIC LARVAE IN AQUARIA CONTAINING SAND AND FLOWING ESTUARINE WATER. AQUARIA CONTAINED: SAND ONLY; A MIXTURE (BY VOLUME) OF 1 PART MUD AND 10 PARTS SAND; 1 PART MUD AND 5 PARTS SAND; OR SAND COVERED BY 0.2 CM MUD. FOR ALL ENVIRONMENTS, ANNELIDS, MOLLUSKS, ARTHROPODS, AND COELENTERATES WERE THE NUMERICALLY DOMINANT PHYLA COLLECTED IN A 1 MM MESH SIEVE AFTER EIGHT WEEKS EXPOSURE; A TOTAL OF 1,025 ANIMALS, REPRESENTING 45 SPECIES, WAS COLLECTED. ANNELIDS AND COELENTERATES WERE SIGNIFICANTLY FEWER (A=0.05) IN AQUARIA CONTAINING DRILLING MUD THAN IN THE CONTROL AQUARIA. ARTHROPODS WERE SIGNIFICANTLY AFFECTED ONLY BY MUD COVER OVER SAND; MOLLUSKS ALSO WERE DIMINISHED IN THIS ENVIRONMENT, BUT NOT SIGNIFICANTLY. EXPOSURE TO CONCENTRATIONS OF DRILLING MUD REDUCED NOT ONLY THE NUMBER OF INDIVIDUALS, BUT ALSO THE FREQUENCY OF OCCURENCE OF MACROBENTHIC SPECIES. THUS, THE AVERAGE NUMBER OF ANNELID SPECIES IN 1 PART MUD: 5 PARTS SAND AQUARIA OR IN MUD-COVERED AQUARIA WAS SIGNIFICANTLY LESS THAN IN CONTROL AQUARIA. THE AVERAGE NUMBER OF ARTHROPOD SPECIES PER AQUARIUM WAS ALSO SIGNIFICANTLY LESS IN MUD-COVER EXPOSURE THAN IN THE CONTROL. DISCHARGE OF LARGE QUANTITIES OF DRILLING MUD AT LEVELS TESTED IN THE LABORATORY COULD ADVERSELY AFFECT THE COLONIZATION OF VARIOUS SUBSTRATA BY BENTHIC ANIMALS IN NATURE.

TAGATZ, M.E., J.M. IVEY, AND M. TOBIA. 1978. EFFECTS OF DOWICIDE G-ST ON DEVELOPMENT OF EXPERIMENTAL ESTUARINE MACROBENTHIC COMMUNITIES. IN: PENTACHLOROPHENOL: CHEMISTRY, PHARMACOLOGY, AND ENVIRONMENTAL TOXICOLOGY. K. RANGA RAO, EDITOR, PLENUM PRESS, NY. PP. 157-163. (ERL,GB 352).

AQUARIA CONTAINING CLEAN SAND RECEIVED A CONTINUOUS SUPPLY OF FLOWING SEAWATER FROM SANTA ROSA SOUND, FLORIDA, MIXED WITH KNOWN QUANTITIES OF DOWICIDE G-ST (79% SODIUM PENTACHLOROPHENATE) FOR THIRTEEN WEEKS. THE MEASURED CONCENTRATIONS OF PENTACHLOROPHENOL (PCP) IN AQUARIA WERE 1.8, 15.8 AND 161 MG/L. AT THE END OF THE EXPERIMENT, MACROFAUNA ESTABLISHED IN CONTROL AND EXPERIMENTAL AQUARIA WAS EXAMINED. MOLLUSKS, ARTHROPODS AND ANNELIDS WERE NUMERICALLY DOMINANT AMONG THE MACROFAUNA. ALTHOUGH EXPOSURE TO 1.8 MG PCP/L HAD NO EFFECT, THE HIGHER CONCENTRATIONS OF PCP CAUSED MARKED REDUCTION IN THE NUMBERS OF INDIVIDUALS AND SPECIES. MOLLUSKS WERE THE MOST SENSITIVE TAXONOMIC GROUP TO PCP. THESE RESULTS AND OUR PREVIOUS STUDIES ON THE EFFECTS OF A NINE-WEEK EXPOSURE TO PCP IN THE ESTABLISHMENT OF MACROBENTHIC COMMUNITIES INDICATE THAT DISCHARGE OF PCP INTO NATURAL WATERS COULD ALTER THE NORMAL COLONIZATION BY BENTHIC ANIMALS AND COULD IMPACT VARIOUS ECOLOGICAL RELATIONSHIPS AMONG LOCALIZED POPULATIONS.

TAGATZ, M.E., J.M. IVEY, AND J.L. OGLESBY. 1979. TOXICITY OF DRILLING-MUD BIOCIDES TO DEVELOPING ESTUARINE MACROBENTHIC COMMUNITIES. NORTHEAST GULF SCI. 3(2):88-95. (ERL,GB 391).

THE EFFECTS OF VARIOUS BIOCIDES, AS USED IN DRILLING MUDS FOR EXPLORATORY DRILLING FOR OIL OFFSHORE, WERE DETERMINED BY COMPARING MACROBENTHIC COMMUNITIES THAT DEVELOPED FROM PLANKTONIC LARVAE IN TREATED AND UNTREATED AQUARIA. SURFLO-B33 AND ALDACIDE WERE TESTED SIMULTANEOUSLY. HARVEST AT SEVEN WEEKS YIELDED 1,941 ANIMALS, REPRESENTING 37 SPECIES OF 6 PHYLA. THE EFFECTS OF SURFLO-B33 (25% DICHLOROPHENOL AND OTHER CHLOROPHENALS) ON THESE COMMUNITIES WERE SIMILAR TO THOSE OF PENTACHLOROPHENOL (TAGATZ ET AL., 1977; 1978), A BIOCIDE KNOWN TO BE TOXIC TO MANY AQUATIC ORGANISMS (RAO, 1978). SIGNIFICANTLY FEWER (A=0.05) CHORDATES, MOLLUSKS, AND ANNELIDS OCCURRED IN 819 MG SURFLO-B33/1 (MEASURED) THAN IN THE CONTROL; MOLLUSKS WERE MOST SENSITIVE AND ALSO SIGNIFICANTLY FEWER IN AQUARIA RECEIVING 41 MG/1. AVERAGE NUMBERS OF ANIMALS AND SPECIES PER AQUARIUM DID NOT SIGNIFICANTLY DECREASE IN ALDACIDE (91% PARAFORMALDEHYDE) AT NOMINAL CONCENTRATIONS OF 15 AND 300 MG/1. THE HIGH TOXICITY OF THE CHLOROPHENOLS TESTED INDICATES THAT THE USE OF ALTERNATIVE BIOCIDES, POSSIBLY PARAFORMALDEHYDE, SHOULD BE CONSIDERED FOR NATURAL WATERS.

TAGATZ, M.E., J.M. IVEY, H.K. LEHMAN, M. TOBIA, AND J.L. OGLESBY. 1980. EFFECTS OF DRILLING MUD ON DEVELOPMENT OF EXPERIMENTAL ESTUARINE MACROBENTHIC COMMUNITIES. IN: SYMPOSIUM: RESEARCH ON ENVIRONMENTAL FATE AND EFFECTS OF DRILLING FLUIDS AND CUTTINGS, JANUARY 21-24, 1980, LAKE BUENA VISTA, FL., VOL. 2. AMERICAN PETROLEUM INSTITUTE, WASHINGTON, DC. PP. 847-865. (ERL,GB 401*).

THE EFFECTS OF DRILLING MUD ON DEVELOPMENT OF ESTUARINE MACROBENTHIC COMMUNITIES, WHICH RESULT FROM SETTLING PLANKTONIC LARVAE, WERE ASSESSED BY COMPARING NUMBER AND SPECIES OF ANIMALS THAT GREW IN UNCONTAMINATED AND CONTAMINATED AQUARIA FOR AT LEAST 7 WEEKS. AQUARIA CONTAINED SAND AND WERE CONTINUOUSLY SUPPLIED WITH UNFILTERED SEAWATER. WE TESTED WHOLE DRILLING MUD, BARITE (MUD-WEIGHTING AGENT), A PARAFORMALDEHYDE-TYPE BIOCIDE (ALDACIDE), AND THREE CHLOROPHENOL-TYPE BIOCIDES (PENTACHLOROPHENOL, DOWICIDE G-ST, AND SURFLO B-33). TESTS WITH WHOLE DRILLING MUD AND BARITE WERE DESIGNED TO DETERMINE THEIR IMPACT AS A COVER (2 OR 5 MM) OVER THE SUBSTRATUM AND WHEN MIXED WITH CLEAN SAND (RATIOS OF 1:10 SAND AND HIGHER). ANNELIDS WERE MOST SENSITIVE TO DRILLING MUD AND BARITE AND SIGNIFICANTLY FEWER (P-0.05) IN ALL CONTAMINATED AQUARIA THAN IN CONTROL AQUARIA. FOR ALL PHYLA, THE AVERAGE NUMBER OF SPECIES PER AQUARIUM WAS SIGNIFICANTLY LESS IN TREATMENTS WITH A COVER OF MUD OR BARITE THAN IN THE CONTROLS. MOLLUSKS WERE PARTICULARLY AFFECTED BY THE CHLOROPHENOL-TYPE BIOCIDES AND SIGNIFICANTLY FEWER (P=0.05) AT CONCENTRATIONS (ACTIVE INGREDIENT IN WATER) OF 7 MICROGRAMS PENTACHLOROPHENOL/1, 18 MICROGRAMS DOWICIDE G/1, AND 10 MICROGRAMS SURFLO B-33/1. NUMBERS OF INDIVIDUALS AND SPECIES OF ANNELIDE PER EXPERIMENTAL AQUARIUM WERE ALSO SIGNIFICANTLY LESS THAN IN CONTROL AQUARIA AT 76 MICROGRAMS PENTACHLOROPHENOL/1, 183 MICROGRAMS DOWICIDE G/1, AND 205 MICROGRAMS SURFLO B-33/1. NUMBERS OF ANIMALS AND SPECIES DID NOT SIGNIFICANTLY DECREASE IN THE PRESENCE OF ALDACIDE AT NOMINAL CONCENTRATIONS (ACTIVE INGREDIENT) AS HIGH AS 273 MICROGRAMS/1. ADVERSE EFFECTS OF DRILLING MUD ON MARINE BENTHOS COULD RESULT FROM TOXIC CONSTITUENTS OR FROM THOSE THAT PHYSICALLY ALTER THE SUBSTRATE.

TAGATZ, M.E., J.M. IVEY, C.E. DALBO, AND J.L. OGLESBY. 1982. RESPONSES OF DEVELOPING ESTUARINE MACROBENTHIC COMMUNITIES TO DRILLING MUDS. ESTUARIES. 5(2):131-137. (ERL,GB 413).

THE EFFECTS OF DRILLING MUD ON DEVELOPMENT OF ESTUARINE MACROBENTHIC COMMUNITIES, WHICH RESULT FROM SETTLING PLANKTONIC LARVAE, WERE ASSESSED BY COMPARING NUMBER AND SPECIES OF ANIMALS THAT GREW IN UNCONTAMINATED AND CONTAMINATED AQUARIA FOR 8 WEEKS. AQUARIA CONTAINED SAND AND WERE CONTINUOUSLY SUPPLIED WITH UNFILTERED SEAWATER. SEVEN DRILLING MUDS, OBTAINED FROM AN ACTIVE EXPLORATORY PLATFORM IN ESTUARINE WATERS, WERE TESTED CONSECUTIVELY AT NOMINAL CONCENTRATIONS OF 0.5, 5, AND 50 PARTS PER MILLION. NUMBERS OF CHORDATES, MOLLUSKS, AND ANNELIDS PER AQUARIUM WERE SIGNIFICANTLY (A=0.05) DECREASED FROM CONTROL NUMBERS IN 50 PPM. A TOTAL OF 13 SPECIES OCCURRED IN 50 PPM COMPARED TO 23 SPECIES IN EACH OF THE OTHER SITUATIONS. GROWTH IN DIAMETER OF MOLGULA MANHATTENSIS WAS AFFECTED IN ALL CONCENTRATIONS OF MUD, THE PERCENTAGE OF LARGE INDIVIDUALS BEING SIGNIFICANTLY LESS THAN IN THE CONTROL.

THOMPSON, JACK H., AND THOMAS J. BRIGHT. 1980. EFFECTS OF AN OFFSHORE DRILLING FLUID ON SELECTED CORALS. IN: SYMPOSIUM: RESEARCH ON ENVIRONMENTAL FATE AND EFFECTS OF DRILLING FLUIDS AND CUTTINGS, JAN. 21-24, 1980, LAKE BUENA VISTA, FL., VOL. 2. AMERICAN PETROLEUM INSTITUTE, WASHINGTON, DC. PP. 1044-1078. (ERL,GB X227*).

SEVEN SPECIES OF CORAL, DICHOCOENIA STOKESII, NONTASTREA ANNULARIS, AGARCIA AGARICITES, ACROPORA CERVICORNIS, PORITES FURCATA, P. ASTREOIDS, AND P. DIVARICATA, WERE EXPERIMENTALLY EXPOSED TO EACH OF THREE CONCENTRATIONS (100, 316, 100 1/1) OF DRILLING MUD (OBTAINED FROM AN OFFSHORE OIL WELLIN THE GULF OF MEXICO), AND CONTROL SEA WATER FOR 96 HOURS TO OBSERVE BEHAVIORAL RESPONSES. EXPERIMENTS WERE CONDUCTED AT CARYSFORT REEF, FLORIDA KEYS, USING CLOSED AQUARIA LOCATED IN THREE METERS OF WATER. POLYP BEHAVIOR WAS DETERMINED WITH SERIAL CLOSEUP PHOTOGRAPHY WHICH ALLOWED COUNTING OF RETRACTED, PARTIALLY RETRACTED, AND NON-RETRACTED POLYPS IN EACH COLONY. RESPONSE TO DRILLING MUD CONCENTRATIONS WAS MEASURED AS PERCENT OF POLYPS RETRACTED. MONTASTREA ANNULARIS, AGARICIA AGARICITES, AND ACROPORA CERVICORNIS WERE KILLED BY EXPOSURE TO 1,000 UL/L MUD. A. CERVICORNIS COLONIES SURVIVED THIS CONCENTRATION IN A REPLICATE EXPERIMENT. ALL CORALS EXCEPT DICHOCOENIA STOKESII AND PORITES DIVARICATA SHOWED SIGNIFICANT (LESS THAN .05) POLYP RETRACTION DURING EXPOSURE TO 100 1/1 MUD CONCENTRATION, 316 UL/L MUD WAS THE MINIMUM CONCENTRATION WHICH INDUCED SIGNIFICANT POLYP RETRACTION IN PORITES DIVARICATA. POLYPS OF DICHOCOENIA STOKESII DID NOT DETECTABLY REACT TO ANY OF THE THREE CONCENTRATIONS.

WHITE, DAVID C., ROBERT H. FINDLAY, STEVEN D. FAZIO, RONALD J. BOBBIE, JANET S. NICKELS, WILLIAM M. DAVIS, GLEN A. SMITH, AND ROBERT F. MARTZ. 1980. EFFECTS OF BIOTURBATION AND PREDATION BY MELLITA QUINQUIESPERFORATA ON SEDIMENTARY MICROBIAL COMMUNITY STRUCTURE. IN: ESTUARINE PERSPECTIVES. VICTOR S. KENNEDY, EDITOR, ACADEMIC PRESS, NEW YORK, NY. PP. 163-171. (ERL,GB X129*).

PROCESSING OF SAND BY SAND DOLLARS (ECHINODERMATA: MELLITA QUINQUIESPERFORATA) RESULTED IN MODIFICATION OF THE BENTHIC MICROBIAL COMMUNITY WITHOUT A SIGNIFICANT EFFECT ON GROSS NUTRIENT BALANCES. MEASURES OF CELLULAR AND MEMBRANE BIOMASS (TOTAL ADENOSINE NUCLEOTIDES, LIPID PHOSPHATE AND CHLOROPHYLL A) WERE ESSENTIALY UNCHANGED. MURAMIC ACID CONCENTRATION AND THYMIDINE INCORPORATION INTO DNA, WHICH ARE MEASURES OF PROKARYOTIC BIOMASS AND ACTIVITY, REMAINED UNCHANGE. TOTAL METABOLIC ACTIVITY, MEASURED AS ACETATE INCORPORATION INTO LIPID, WAS UNCHANGED. LIPID GLYCEROL AND THE INOSITOL AND GLUCOSAMINE REMAINING IN THE EXTRACTED RESIDUE WERE REDUCED IN THE PROCESSED SEDIMENT, AS WAS SULPHOLIPID BIOSYNTHESIS. FATTY ACIDS CHARACTERISTIC OF PROKARYOTES WERE ENRICHED WHEREAS FATTY ACIDS CHARACTERISTIC OF MICROEUKARYOTES DECREASED IN PROCESSED SANDS. THE SAME WAS TRUE FOR THE LIPID NEUTRAL CARBOHYDRATES. EXAMINATION OF MEIOFAUNA SHOWED SIGNIFICANT REDUCTION IN FORAMINIFERA, SUGGESTING THAT SAND DOLLARS ARE SELECTIVE PREDATORS FOR A PORTION OF THE NONPHOTOSYNTHETIC MICROEUKARYOTES, HAVING LITTLE EFFECT ON THE BIOMASS OR METABOLIC ACTIVITY OF BENTHIC PROKARYOTES.

WHITE, D.C., R.J. BOBBIE, J.S. NICKELS, S.D. FAZIO, AND W.M. DAVIS. 1980. NONSELECTIVE BIOCHEMICAL METHODS FOR THE DETERMINATION OF FUNGAL MASS AND COMMUNITY STRUCTURE IN ESTUARINE DETRITAL MICROFLORA. BOT. MAR. 23(4):239-250. (ERL,GB X128*).

ASSAY OF LIPID AND CELL WALL COMPONENTS CAN READILY PROVIDE DIFFERENTIATION IN RECIPROCAL MIXTURES OF BACTERIA AND FUNGAL MONOCULTURES. TO TEST NATURAL MICROBIAL ASSEMBLIES, SMALL PLASTIC SHEETS WERE EXPOSED IN A SUBTROPICAL ESTUARY. THE SHEETS WERE THEN TRANSFERRED TO A LABORATORY WHERE ESTUARINE ENVIRONMENTS THAT INHIBIT PROKARYOTIC GROWTH AND STIMULATED FUNGAL GROWTH WERE COMPARED WITH AND ENVIRONMENT WHERE EUKARYOTIC GROWTH WAS INHIBITED AND PROKARYOTIC GROWTH WAS STIMULATED. THE MORPHOLOGY DETERMINED BY SCANNING ELECTRON MICROSCOPY SHOWED TYPICAL MYCELIAL NETWORKS WHERE EUKARYOTIC GROWTH WAS STIMULATED AND NONE WHERE INHIBITED. THE STIMULATION OF EUKARYOTIC GROWTH PRODUCED A GREATER BIOMASS MEASURED IN TERMS OF LIPID PHOSPHATE, RESPIRATORY ACTIVITY OR EXTRACTABLE ADENOSINE NUCLEOTIDES, BUT WITH A SLOWER SYNTHESIS OF PHOSPHOLIPIDS AND DNA AND A SMALLER CONCENTRATION ON MURAMAIC ACID (A UNIQUE PROKARYOTE WALL COMPONENT). THE STIMULATION OF EUKARYOTIC GROWTH INCREASED THE RATE OF SULPHOLIPID SYNTHESIS RELATIVE TO DNA OR PHOSPHOLIPID SYNTHESIS.

WHITE, DAVID C. 1982. BIOCHEMICAL DETERMINATION OF BIOMASS AND COMMUNITY STRUCTURE OF ESTUARINE DETRITAL AND SEDIMENTARY MICROBIOTA. IN: IMPACT OF XENOBIOTIC CHEMICALS ON MICROBIAL ECOSYSTEMS, U.S. FISH WILDL. SERV. TECH. PAP. NO. 107. U.S. FISH AND WILDLIFE SERVICE, WASHINGTON, DC. PP. 22-28. (ERL,GB X375).

SEDIMENTARY MICROBIAL BIOMASS, METABOLIC ACTIVITY, NUTRITIONAL STATUS, AND COMMUNITY STRUCTURE WERE DETERMINED BY THE ANALYSIS OF EXTRACTABLE LIPIDS AND HYDROLYSIS PRODUCTS OF THE LIPID EXTRACTED RESIDUE. THESE METHODS HAVE BEEN VALIDATED BY ANALYSIS OF MIXTURES OF MICROBIAL MONOCULTURES; BY COMPARISONS WITH MONOCULTURES ISOLATED FROM MICROBIAL ASSEMBLIES; BY SCANNING ELECTRON MICROSCOPIC ANALYSIS OF DETRITAL MICROBIAL ASSEMBLIES MANIPULATED WITH ANTIBIOTICS, NUTRIENTS, AND LIGHT; AND BY MEASUREMENTS OF THE EFFECTS OF GRAZING BY SELECTIVE DEPOSIT FEEDING INVERTEBRATES. THESE METHODS HAVE SHOWN THAT MG/L CONCENTRATIONS OF XENOBIOTICS IN FLUIDS USED IN OIL AND GAS WELL DRILLING SIGNIFICANTLY MODIFY THE BIOMASS AND COMMUNITY STRUCTURE OF MICROBIAL ASSEMBLIES COLONIZING MARINE SAND. SUCH METHODS ENABLE ESTIMATION OF VALIDITY OF THE USE OF MICROCOSM TEST SYSTEMS IN PREDICTING THE IMPACTS OF XENOBIOTICS IN THE FIELD. THESE METHODS COULD GREATLY STRENGTHEN THE LEGAL APPLICABLILITY OF THE DATA FOR USE BY REGULATORY AGENCIES IN PROTECTION ESTUARINE ECOSYSTEMS.

WIERNICKI, C. 1984. ASSIMILATION EFFICIENCY BY PROCAMBARUS CLARKII FED ELODEA (EGERA DENSA) AND ITS PRODUCTS OF DECOMPOSITION. AQUACULTURE. 36(3):203-215. (ERL,GB X372*).

ELODEA CUT INTO TWO INITIAL PARTICLE SIZES (2.0 CM SECTIONS AND 3.0 MM(2) FRAGMENTS) UNDERWENT MICROBIAL DECOMPOSITION FOR PERIODS OF 0, 15, 33, AND 45 DAYS, AND THEN WAS FED TO FOUR SIZE CLASSES OF CRAYFISH (2.0, 3.5, 5.0, AND 9.0 CM). ASSIMILATION EFFICIENCY WAS DETERMINED BY CONOVER'S METHOD. ALL FOUR SIZE CLASSES OF CRAYFISH ASSIMILATED 15-DAY DETRITUS MORE EFFICIENTLY THAN 0-DAY DETRITUS. TWO-CM CRAYFISH ASSIMILATED 33-DAY DETRITUS MORE EFFICIENTLY THAN 15- OR 0-DAY DETRITUS. IN ALL OTHER CASES, ASSIMILATION EFFICIENCY WAS REDUCED. RADIOTRACER TECHNIQUES UTILIZING 14C WERE USED TO DETERMINE THE PERCENTAGE OF CARBON ASSIMILATED IN THE FORM OF PLANT FRAGMENTS COMPARED WITH THE PERCENTAGE ASSIMILATED IN THE FORM OF MICROORGANISMS. RESULTS INDICATE AN INVERSE RELATIONSHIP BETWEEN CRAYFISH SIZE AND THE PERCENTAGE OF CARBON ASSIMILATED IN THE FORM OF MICROORGANISMS.

YINGST, J. Y., AND D. C. RHOADS. IN PRESS. STRUCTURE OF SOFT-BOTTOM BENTHIC COMMUNITIES IN THE VICINITY OF THE TEXAS FLOWER GARDEN BANKS GULF OF MEXICO. ESTUARINE COASTAL SHELF SCI. (ERL,GB 503).

BIOLOGICAL AND SEDIMENTOLOGICAL SAMPLES WERE OBTAINED IN JUNE 1980 FROM BOX CORES TAKEN IN 100-200 METERS OF WATER ON SANDY-MUD SEDIMENTS NEAR THE EAST AND WEST FLOWER GARDEN BANK (FGH) REEFS, ON THE TEXAS-LOUISIANA CONTINENTAL SHELF. THE OBJECTIVE WAS TO OBTAIN NEEDED AND UNKNOWN BASELINE INFORMATION ABOUT SEDIMENTARY PARAMETERS AND ORGANISMS OF THE FGB ENVIRONMENT TO ALLOW INFERENCES TO BE MADE ABOUT THE POTENTIAL EFFECTS OF PHYSICAL DISTURBANCES OF THE SEAFLOOR ON THE INDIGENOUS BENTHOS. BOTH MICROBIAL ATP AND BACTERIAL BIOMASS ARE LOWER THAN REPORTED FOR GEORGIA BIGHT SHELF, BRAZIL-AMAZON RIVER SHELF, CAP BLANC, WEST AFRICAN SHELF, WESTERN COAST OF NORWAY, AND LONG ISLAND SOUND. BACTERIAL COUNTS ARE COMPARABLE TO THE AMAZON RIVER SHELF AND LOWER THAN THOSE RECORDED FOR THE EAST CHINA SEA. MODERATE TO LOW STANDING STOCKS OF BENTHOS FURTHER SUGGEST THAT THIS AREA OF THE GULF OF MEXICO IS A RELATIVELY OLIGOTHROPHIC SYSTEM FOR INFAUNAL BENTHIS CONSUMERS. THE GREATEST POTENTIAL DELETERIOUS PHYSICAL DISTURBANCE TO THE FGB SYSTEM IS AN INFLUX OF DRILLING MUDS FROM NEARBY OIL DRILLING OPERATIONS. HIGHER ORDER SUCCESSIONAL STAGES ARE IN GENERAL ADVERSELY AFFECTED TO A GREATER EXTENT THAN PIONEERING STAGES BY PHYSICAL DISTURBANCE. IN THE TEXAS-LOUISIANA SHELF REGION, DILUTION OF AN ALREADY OLIGOTROPHIC SYSTEM BY INERT BARIUM SULPHATE WOULD BE EXPECTED TO RESULT IN EVEN LOWER STANDING STOCKS OF PIONEERING INVERTEBRATES THAN MIGHT OTHERWISE OCCUR.

APPENDIX B

PUBLISHED PAPERS NOT INCLUDED IN LITERATURE REVIEW AND MANUSCRIPTS IN PREPARATION, ERL/GB DRILLING FLUIDS RESEARCH PROGRAM, 1976-1984.

PUBLISHED PAPERS NOT INCLUDED IN LITERATURE REVIEW

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APPENDIX C

PESA DRILLING FLUIDS SAMPLE DESCRIPTIONS

PESA DRILLING FLUID SAMPLE DESCRIPTION

DRILLING FLUID SAMPLE CODE: MIBLKA51

GENERAL SAMPLE DESCRIPTION: Seawater lignosulfonate

DATE/TIME SAMPLE RECEIVED: 11/11/81

LOCATION OF WELL: Mustang Island Block A-51
Approximately 72 miles SE of mouth of Corpus Christi Bay

ACTIVITY AT TIME OF SAMPLING: Drilling

DEPTH OF WELL: 7471
SOLIDS CONTENT (% by VOL): 11
FLUID WEIGHT (ppg): 10
LIQUID CONTENT (% by VOL) OIL/WATER: 89%
SAND CONTENT (% by VOL): --
pH: 10.4
FLOWLINE TEMP. (°F): 115°

REPORTED COMPONENTS

COMPONENT	% BY WT.
Barite	75
Bentonite	15
Chrome lignosulfonate	2
Caustic soda	2
Lignite	4
Lime	0.66
Soda Ash	0.66
Phosphate	0.66

PESA DRILLING FLUID SAMPLE DESCRIPTION

DRILLING FLUID SAMPLE CODE: AN31

GENERAL SAMPLE DESCRIPTION: Seawater lignosulfonate

DATE/TIME SAMPLE RECEIVED: 11/18/81

LOCATION OF WELL: Mississippi Canyon Block 148
Approx. 12 miles south of mouth of Mississippi River

ACTIVITY AT TIME OF SAMPLING: Tripping

DEPTH OF WELL: 11732
FLUID WEIGHT (ppg): 12.3
LIQUID CONTENT (% by VOL) OIL/WATER: 0/82
SAND CONTENT (% by VOL): .75
pH: 12

SOLIDS CONTENT (% by VOL): 18
FLOWLINE TEMP. (°F): N.A.

REPORTED COMPONENTS

COMPONENT	% BY WT.
Barium sulfate	86.6
Bentonite	6.6
Aluminum stearate	0.002
Polyanionic cellulosic polymer	0.408
Calcium hydroxide	0.024
Lignosulfonate	1.6
Lignite	1.506
Mica	0.166
Pecan hulls	0.289
Surface-active dispersible liquid	0.031
NaOH	2.8
Granules/flakes/fibers	0.025

PESA DRILLING FLUID SAMPLE DESCRIPTION

DRILLING FLUID SAMPLE CODE: SV76

GENERAL SAMPLE DESCRIPTION: Seawater lignosulfonate

DATE/TIME/ SAMPLE RECEIVED: 12/22/81

LOCATION OF WELL: Vermilion Block 76
Approx. 22 miles SSW of Cheniere Au Tigre, LA

ACTIVITY AT TIME OF SAMPLING: N.A.

DEPTH OF WELL: N.A.
SOLIDS CONTENT (% by VOL): 41
FLUID WEIGHT (ppg): 18.8
LIQUID CONTENT (% by VOL) OIL/WATER: 2/57
SAND CONTENT (% by VOL): TR
pH: 11.1
FLOWLINE TEMP. (°F): N.A.

REPORTED COMPONENTS

COMPONENT	CONCENTRATION, 1 lbs./bbl.
Bentonite	18
Chromium lignosulfonate	6-9
Causticized lignite	6-9
Soltex	4
Polymer treated lignite	2
Sodium dichromate	0.2
Sodium hydroxide	-

weighted to 18.8 lb./gal. with barite

PESA DRILLING FLUID SAMPLE DESCRIPTION

DRILLING FLUID SAMPLE CODE: P1

GENERAL SAMPLE DESCRIPTION: Lightly treated lignosulfonate

DATE/TIME SAMPLE RECEIVED: 4/15/82

LOCATION OF WELL: Eugene Island Block 126
Approx. 35 miles south of Atchafalaya Bay, LA

ACTIVITY AT TIME OF SAMPLING: Drilling

DEPTH OF WELL: 14,144
SOLIDS CONTENT (% by VOL) 32
FLUID WEIGHT (ppg): 16.4
LIQUID CONTENT (% by VOL) OIL/WATER: 2/66
SAND CONTENT (% by VOL): TR
pH: 12
FLOWLINE TEMP. (°F): 100°

REPORTED COMPONENTS

COMPONENT	% BY WT.
Barite	87.2
Bentonite	7.9
Lignite	0.999
Lignosulfonate	1.8
NaOH	1.011
Polyanionic cellulosic polymer	0.169
Detergent	0.007
Sodium Carbonate	0.154
Attapulgite	0.095
Asbetos	0.073
Aluminum stearate	0.002
Fatty acids, sulfonates & asphaltic materials	0.469
Nut shells	0.025
Nonionic surface active agent	0.005
Anionic surfactants	0.013
Mica	0.045

PESA DRILLING FLUID SAMPLE DESCRIPTION

DRILLING FLUID SAMPLE CODE: P2

GENERAL SAMPLE DESCRIPTION: Freshwater lignosulfonate

DATE/TIME SAMPLE RECEIVED: 4/16/82

LOCATION OF WELL: Nueces Co., Texas
Vicinity of Corpus Cristi Bay

ACTIVITY AT TIME OF SAMPLING: Drilling

SOLIDS CONTENT (% by VOL): 39

DEPTH OF WELL: 13,625
FLUID WEIGHT (ppg): 17
LIQUID CONTENT (% by VOL) OIL/WATER: 0/61
SAND CONTENT (%by VOL): .25
pH: 13

FLOWLINE TEMP. (°F): N.A.

REPORTED COMPONENTS

COMPONENT	% BY WT.
N.A.	

PESA DRILLING FLUID SAMPLE DESCRIPTION

DRILLING FLUID SAMPLE CODE: P3

GENERAL SAMPLE DESCRIPTION: Lime mud

DATE/TIME SAMPLE RECEIVED: 4/19/82

LOCATION OF WELL: Lake Hatch, Terrebonne, LA

ACTIVITY AT TIME OF SAMPLING: Logging

DEPTH OF WELL: 17,195
FLUID WEIGHT (ppg): 18.1
LIQUID CONTENT (% by VOL) OIL/WATER: 3/57
SAND CONTENT (% by VOL): TR
pH: 11.5

SOLIDS CONTENT (% by VOL): 40

FLOWLINE TEMP. (°F): 100°

REPORTED COMPONENTS

COMPONENT	% BY WT.

N.A.

PESA DRILLING FLUID SAMPLE DESCRIPTION

DRILLING FLUID SAMPLE CODE: P4

GENERAL SAMPLE DESCRIPTION: Freshwater lignosulfonate

DATE/TIME SAMPLE RECEIVED: 4/21/82

LOCATION OF WELL: Sea Breeze, Chambers Co., TX
Vicinity of Galveston Bay

ACTIVITY AT TIME OF SAMPLING: Drilling

DEPTH OF WELL: 11,958
FLUID WEIGHT (ppg): 16.1
LIQUID CONTENT (% by VOL) OIL/WATER: 0/66
SAND CONTENT (% by VOL): .25
pH: 9.5

SOLIDS CONTENT (% by VOL): 34

FLOWLINE TEMP. (°F): 130°

REPORTED COMPONENTS

COMPONENT	% BY WT.

N.A.

PESA DRILLING FLUIDS SAMPLE DESCRIPTIONS

DRILLING FLUID SAMPLE CODE: P5

GENERAL SAMPLE DESCRIPTION: Freshwater/saltwater lignosulfonate

DATE/TIME SAMPLE RECEIVED: 4/28/82

LOCATION OF WELL: Lake Chiert, St. Martin Parish, LA

ACTIVITY AT TIME OF SAMPLING: TIH

DEPTH OF WELL: 12,948
FLUID WEIGHT (ppg): 18.3
LIQUID CONTENT (% by VOL) OIL/WATER: 2/62
SAND CONTENT (% by VOL): 0
pH: 10.5

SOLIDS CONTENT (% by VOL): 36

FLOWLINE TEMP. (°F): 117°

REPORTED COMPONENTS

COMPONENT	CONCENTRATION, lb./bbl.
Bentonite	18
Chromium lignosulfonate	6
Desco	4
Drispac	3
Nut Shell	2
Mica	3
Causticized lignite	7
Soltex	5
Sodium hydroxide	

Barite to 18.4 lb./gal.

PESA DRILLING FLUID SAMPLE DESCRIPTION

DRILLING FLUID SAMPLE CODE: P6

GENERAL SAMPLE DESCRIPTION: Low solids nondispersed

DATE/TIME SAMPLE RECEIVED: 6/11/82

LOCATION OF WELL: LAFOURCHE #23 Louisiana

ACTIVITY AT TIME OF SAMPLING: N.A.

DEPTH OF WELL: N.A.
FLUID WEIGHT (ppg): 12.5
LIQUID CONTENT (%by VOL) OIL/WATER: 0/90
SAND CONTENT (% by VOL): TR
pH: 8.5

SOLIDS CONTENT (% by VOL): 10

FLOWLINE TEMP. (°F): N.A.

REPORTED COMPONENTS

COMPONENT	% BY WT.

N.A.

PESA DRILLING FLUID SAMPLE DESCRIPTION

DRILLING FLUID SAMPLE CODE: P7

GENERAL SAMPLE DESCRIPTION: Lightly treated lignosulfonate

DATE/TIME SAMPLE RECEIVED: 6/14/82

LOCATION OF WELL: South Marsh Island Block 222
12 miles south of mouth of Vermilion Bay

ACTIVITY AT TIME OF SAMPLING: Tripping

DEPTH OF WELL: 12,296
SOLIDS CONTENT (% by VOL): 13
FLUID WEIGHT (ppg): 8.8
LIQUID CONTENT (% by VOL) OIL/WATER: 0/87
SAND CONTENT (% by VOL): .75
pH: 10.5
FLOWLINE TEMP. (°F): N.A.

REPORTED COMPONENTS

COMPONENT	% BY WT.
Barite	1.22
Bentonite	41.57
Attapulgite	14.08
CaOH	5.3
NaOH	20.79
Sodium carbonate	0.25
Lignosulfonate	9.47
Lignite	5.72
PCP	0.22
Aluminum stearate	0.05
Sodium acid pyrophosphate	0.49
Detergent	0.10
Synergistic polymer blend	0.74

PESA DRILLING FLUID SAMPLE DESCRIPTION

DRILLING FLUID SAMPLE CODE: P8

GENERAL SAMPLE DESCRIPTION: Heavily treated lignosulfonate

DATE/TIME SAMPLE RECEIVED: 7/28/82

LOCATION OF WELL: Brazos Block 409
Approx. 18 miles ESE of Matagorda, TX

ACTIVITY AT TIME OF SAMPLING: Drilling

DEPTH OF WELL: 12,338
FLUID WEIGHT (ppg): 17.8
LIQUID CONTENT (% by VOL) OIL/WATER: 0/63
SAND CONTENT (% by VOL): .75
pH: 11.5

SOLIDS CONTENT (% by VOL) 37

FLOWLINE TEMP. (°F): 119°

REPORTED COMPONENTS

COMPONENT	% BY WT.
Barite	58.4
Bentonite	24.0
Sodium carbonate	0.092
NaOH	3.584
Ferrochrome lignosulfonate	0.276
Chipped formica	0.276
Sodium bicarbonate	0.129
Sodium acid pyrophosphate	0.377
Lignite	5.486
Lignosulfonate	5.5
Aluminum stearate	0.044
Walnut hulls	0.141
PCP	0.253
Pecan hulls	0.708
Sodium chromate	0.046
Chrome lignosulfonate	0.44

APPENDIX D

SOURCE AND REPORTED COMPOSITION OF EIGHT LABORATORY-PREPARED GENERIC DRILLING FLUIDS RECEIVED AT U.S. EPA, GULF BREEZE, FLORIDA

Source and reported composition of eight generic drilling fluids received at U.S. EPA, Gulf Breeze Florida.

		Composition	
Drilling Fluid	Source	Component	Concentration
EPA-83-001, KCl Polymer Mud	Chromalloy	KCl	50.0 grams (g)
		Drispac (Super-Lo)	0.5 g
		X-C Polymer	1.0 g
		Barite	283.2 g
		Starch	2.0 g
		Seawater	257.6 milliliters (ml)
EPA-83-002, Seawater Lignosulfonate Mud	IMCO Services	Attapulgite	30.0 pounds per barrel (ppbbl)
		Chrome Lignosulfonate	15.0 ppbbl
		Lignite	10.0 ppbbl
		Polyanionic Cellulose	0.25 ppbbl
		Caustic	To pH 10.5-11.0
		Barite	To bring mud weight to 17-18 pounds per gallon (ppg)
		Seawater	As needed
EPA-83-003, Lime Mud	Hughes	Benitonite	20.06 g
		Lime	5.01 g
		Barite	281.81 g
		Chrome Lignosulfonate	15.04 g
		Caustic	1.00 g
		Lignite	8.02 g
		Distilled Water	257.04 ml
EPA-83-004, Non-dispersed mud	Newpark Drilling Fluids	Bentonite	13.0 ppbbl
		Acrylic Polymer (for suspension)	0.5 ppbbl
		Acrylic Polumer (for fluid loss control)	0.25 ppbbl
		Barite	190.7 ppbbl
		Deionized Water	299.6 ppbbl

(continued)

EPA-83-005, Spud mud	NL Baroid	Bentonite	12.5	ppbbl
		Lime	0.5	ppbbl
		Barite	50.0	ppbbl
		Seawater/Freshwaster	1.0	bbl
		Caustic	To pH 10.0	
EPA-83-006, SW/FW Gel Mud	Milchem	Bentonite	20.0	ppbbl
		Polyaninic Cellulose	0.50	ppbbl
		Sodium Carboxymethly Cellulose	0.25	ppbbl
		Barite	20.0	ppbbl
		Sodium Hydroxide	To pH 9.5	
		Seawater/Freshwater, 1:1	As needed	
EPA-83-007, Lightly Treated Lignosulfonate Mud	Magobar Dresser	Bentonite	20.0	ppbbl
		Chrome Lignosulfonate	5.0	ppbbl
		Lignite	3.0	ppbbl
		Soda Ash	1.0	ppbbl
		Carboxymethyl Cellulose	0.5	ppbbl
		Barite	178.5	ppbbl
EPA-83-008, Lignosulfonate Freshwater Mud	Dowell	Bentonite	15.0	g
		Chrome Lignosulfonate	15.0	g
		Lignite	10.0	g
		Carboxymethyl Cellulose	0.25	g
		Sodium Bicarbonate	1.0	g
		Barite	487.0	g
		Deionized Water	187.0	ml

CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE MINERAL OIL USED IN THE LABORATORY-PREPARED GENERIC DRILLING FLUID TESTS

1. Mineral oil analysis reported by IMCO Services, drilling fluid #2

Boiling range (IBP-FBP)	500-610°F
Vapor pressure	0.008
Vapor density	>8
Solubility in water @100°F	30 ppm
Specific gravity	0.845
Percent volatile by volume (%)	100
Evaporation rate	<0.01
Flash point (Pensky-Martens)	255°F

2. Mineral oil analysis reported by Dowell, drilling fluid #8

Chemical name	Paraffin - base oil
Chemical family	Petroleum hydrocarbon
Formula	Complex misture of petroleum hydrocarbons
Boiling point, IBP, °F	500
FBP, °F	610
Vapor pressure (mm Hg), 20°C	0.008
Vapor density (air @ 1)	>8
Solubility in water @ 100°F, ppm	30
Specific gravity (water = 1)	0.845
Percent volatile by volume, %	100; evaporates slowly at 100°F
Evaporation rate (n-Butyl acetate = 1)	<0.01
Appearance and odor	Clear light color. Slight kerosenic odor.
Gravity, °API at 60°F	35.8
Flash point, COC, °F	258 (Pensky - Martens 255°F)
Pour point, °F	5
Color, ASTM D 1500, Saybolt color	28
Viscosity, cSt at 40°C	4.2
SSU at 100°F	41.0

This oil is stable, but strong oxidants such as liquid chlorine, concentrated oxygen, and sodium or calcium hypochlorite should be avoided.